

NH FIELD GUIDE

Residential New Construction

Energy Efficient Construction

ENERGY STAR® Homes • New Hampshire Energy Code

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2009 Building Code Updates to the NH Residential New Construction Field Guide Provided by:

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Introduction

What is “energy efficient” construction? Many people picture a space-age house, with a wall of south-facing glass. Others think about solar power or passive solar heating. Still others think of superinsulation and high-tech windows. Energy efficient construction can include these features, but it does not need to.

Any home design can be energy efficient, and with careful planning, additional construction costs can be minimal. Builders who use the “house as a system” concept to plan and build their homes will have happier customers, more referrals and fewer callbacks, which in the long run will more than pay for any added costs. This guide serves as a starting point to help designers and builders understand the system approach, with an emphasis on meeting the requirements of the energy code and the ENERGY STAR for New Homes Program.

About this guide

The purpose of this guide is to provide an overview of energy efficient residential new construction in the Northeast. The text and drawings in this guide focus on three main subjects:

- **New Hampshire Residential Energy Code**—New Hampshire has adopted a slightly modified version of the 2009 International Energy Conservation Code (IECC). Although there are some state-specific differences, most of the code references in the guide can be used generally for any nearby state with an IECC-based energy code. In addition, requirements from the newly-developed 2012 version of the IECC are included throughout for reference.
- **ENERGY STAR for New Homes Program**—The Environmental Protection Agency’s ENERGY STAR for New Homes Program has set a benchmark for energy efficient new construction nationwide. Through the ENERGY STAR program, any home can be recognized as having met the EPA’s guidelines for improved energy performance. This guide serves as a summary of the key components of a successful ENERGY STAR project.
- **A systems approach to building**—Understanding the way different components and materials interact in a building can reduce moisture problems, indoor air quality complaints, combustion safety problems, ice dams, and other expensive callbacks. This guide provides an overview of the key components of “house as a system” building, with a focus on energy performance.

Format

This guide is divided into sections that follow a typical construction sequence. Each section has convenient tabs marked on the edge of the page (e.g. foundation, framing, etc.). There are also special sections on the energy code, on ENERGY STAR, and on the “house as a system” approach to building.

The purpose of this guide is to provide an overview of the important issues related to building an energy efficient new home, and also to serve as a handy field reference that designers, builders and trades people can use at every step of the construction process. Each chapter has the following features in common:

- **Energy Code**—The opening section of the chapter outlines what parts of the energy code you must pay attention to during that stage in the construction process. References are made to the code document itself so you can find the actual code language that relates to your situation.

With the exception of Chapter 1 (which is devoted entirely to the energy code), energy code requirements are highlighted in blue.

Non-energy code requirements that are cited in the IECC are both highlighted in blue and outlined in a blue box.

Other (non-energy) code requirements that may be related to an energy concern are outlined by a blue box. Most of these requirements are drawn from the International Residential Code (IRC) for One- and Two-Family Dwellings (see Appendix B for ordering information).

Energy code requirements from the new 2012 IECC are included for reference and highlighted in grey.

- **ENERGY STAR**—Further suggestions are made about what steps you may take to help ensure ENERGY STAR guidelines are met at every step. Included are some suggestions about how costs in one area may be traded off against reduced costs in another area.

- **Going further**—This guide is intended to be a concise reference; there are numerous situations which are beyond its scope. There are many references listed in Appendix B for further reading. One of these resources stands out as exemplary, thorough, and easy to understand—the Energy & Environmental Building Association (EEBA) Cold Climate Builder’s Guide. The EEBA Builder’s Guide, referenced as such throughout this book, is an ideal resource for further reading and more detail drawings. See Appendix B for ordering information.

- **Detail drawings**—Most of the drawings in this guide are found at the end of each chapter. The drawings have shaded notes that refer to code requirements. In all drawings, the dotted line (in color) indicates the location of the primary air barrier.

Remember that this book is only intended as a guide. Make sure all construction details are included in your plans, and reviewed and approved by your local building official prior to project commencement. If instances occur where local code and regulatory requirements and the recommendations in this guide are not in agreement, the authority having jurisdiction should be consulted, and/or the local code and regulatory requirements should prevail. Be aware that the local code official may ask for engineering or other confirmation of the integrity of some of the design examples in this guide.

1

The New Hampshire Energy Code

This Guide Is Not the Code

The current residential energy code for New Hampshire is the 2009 International Energy Conservation Code (IECC). This guide attempts to portray these energy code requirements as completely and accurately as possible at the date of publication. However, building codes are subject to interpretation, as well as periodic changes. If you have any questions about the details of the code language, refer to the actual language in the current version of the code (see Appendix B for ordering information). Wherever possible, references are made to the specific section number from the code so you can look it up. If questions regarding the NH Energy Code arise, contact the New Hampshire Public Utilities Commission at (603) 271-6306 (see Appendix B for complete contact information).

New Hampshire Amendments to the IECC 2009

The NH Building Code Review Board adopted two important amendments to the IECC 2009.

Log Homes (IECC 402.1.1)—Log walls must comply with ICC400, with a minimum thickness of 5" or greater. All windows in log walls must have an area-weighted average U-factor of 0.31 or less. In addition, the minimum efficiency of gas heating systems is 90 AFUE and 84 AFUE for oil systems.

Circulating Hot Water System Piping (IECC 403.4)—All circulating service hot water piping must be insulated to at least R-4. Circulating hot water systems must also include an automatic or readily accessible manual switch that can turn off the hot water circulating pump when the system is not in use.

Applicability (IECC 101.4)

The 2009 IECC applies to all types of construction, both residential (IECC Chapter 4) and commercial (IECC Chapter 5). The focus of this guide is on low-rise (three stories high or less), residential, new construction (detached one- and two-family dwellings and low rise multifamily buildings, including townhouses) as well as additions, alterations, and repairs to existing buildings. The 2009 IECC applies to changes in occupancy or use, as well as, changes in space conditioning.

Additions, Alterations and Renovations

New additions, alterations and renovations to existing buildings must meet the requirements of the Energy Code for those portions of the building that are altered. Unaltered portions of the building do not need to comply. An addition, alteration or renovation can comply by itself or in combination with the existing building, as a single building. See page 12 for more information.

IECC 2009 does not apply to:

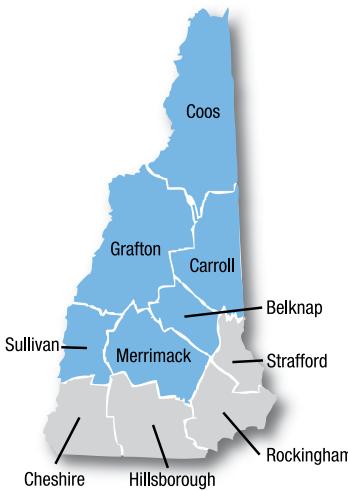
- historic buildings
- low-energy buildings (energy usage less than 3.4 Btu/h·ft² or 1.0 watt/ft² of floor area)
- unconditioned buildings or spaces

Climate Zones

Climate zones from the table below should be used to determine the applicable prescriptive requirements throughout this guide.

County	Climate Zone
Belknap	6
Carroll	6
Cheshire	5
Coos	6
Grafton	6
Hillsborough	5
Merrimack	6
Rockingham	5
Strafford	5
Sullivan	6

Town of Durham - locally adopted and requires compliance with Climate Zone 6 provisions of the 2012 IECC.



How the Code Works

In practice, code compliance has four major elements, which are summarized below:

- General Requirements
- Compliance Analysis
- Documentation
- Plan Review and Field Inspections

General Requirements

The following is a summary of the general requirements (referred to in the code as mandatory provisions). You must follow all of the requirements that are applicable to your building project, regardless of the method that is chosen to demonstrate energy code compliance.

- **Air leakage (IECC 402.4)**—Leaks must be sealed between conditioned space and outdoors, and between conditioned space and unconditioned space. The code specifies locations that must be sealed, and gives examples of ways to seal them. In addition, air sealing must be verified by either a visual inspection or blower door testing. Many examples of acceptable air sealing are found in Chapters 6 and 11, with code requirements highlighted in blue. Also refer to Appendix C – NH's EC-1 Form and Air Barrier and Insulation Inspection Criteria Checklist.
- **Maximum window U-factor (IECC 402.5)**—In New Hampshire, the area weighted U-factor (or U-value), the rate of heat loss of a window assembly, the lower the number the better, the greater a window's resistance to heat flow and the better its insulating properties, shall not exceed 0.35 for windows (0.31 if log walls) and 0.60 for skylights.
- **Mechanical systems (IECC Section 403)**—This section has requirements for controls, duct construction, duct sealing and insulation, pipe insulation, mechanical ventilation and equipment sizing. See Chapters 8 and 9 for specific requirements.

Compliance Analysis

Before you start building, you need to prepare a design that ensures you will comply with the code. In fact, you must do this before you can get a building permit. This is no different from any other part of the code, such as egress requirements, structural loads, etc. There are only two methods that can be used to demonstrate energy code compliance; compliance can be demonstrated prescriptively (IECC Section 402) or it can be done using a simulated performance alternative (formerly referred to as "Systems Analysis," see IECC Section 405). In either case, the list of specifications associated with demonstrating compliance should include the insulation R-values for all floors, walls and ceilings and the U-factors for all windows, doors and skylights. **Note that the comments in the illustrations related to code details do not**

mention R-values. That is because the R-values are determined by your compliance analysis. Most of the code-related notes apply to the general requirements (summarized on the previous page).

Thermal Boundary

Before you do a compliance analysis, it is important to define the thermal boundary of the building. See page 14 for more about the thermal boundary.

Methods of Compliance: Prescriptive and Performance (IECC Section 402)

This method allows you to look up R-values and U-factors from tables (IECC Tables 402.1.1 and 402.1.3). The prescriptive specifications from these tables provide **minimum performance values** for components of the thermal boundary, based on the climate zone of the location where you are intending to build. New Hampshire is divided into two climate zones (5 and 6), the building thermal envelope must meet the prescriptive requirements based on the climate zone specified previously on pg. 14. Those specifications are as follows:

Table 1.1 Prescriptive Specifications for New Hampshire (extracted from IECC 2009 Table 402.1.1)^a

Climate Zone	5	6
Window U-Factor	0.35	0.35
Skylight U-Factor	0.60	0.60
Ceiling R-Value	R-38	R-49
Wall R-Value	20 or 13+5 ^{d,f}	20 or 13+5 ^{d,f}
Floor R-Value	30 ^e	30 ^e
Foundation Wall R-Value ^b	10/13	15/19
Slab R-Value & Depth ^c	10, 2 ft.	10, 4 ft.
Crawl Space Wall R-Value	10/13	10/13

^a R-values are minimums. U-factors and SHGC are maximums.

^b The first R-value applies to continuous insulation, the second to framing cavity insulation; either insulation meets the requirement.

^c R-5 must be added to the required slab edge R-value(s) for heated slabs (e.g. radiant slabs).

^d “13+5” means R-13 cavity insulation plus R-5 insulated sheathing. If structural sheathing covers <= 25% of the exterior, insulated sheathing is not required where structural sheathing is used. If >25%, structural sheathing shall be supplemented with insulated sheathing of at least R-2.

^e Or insulation sufficient to fill the framing cavity, R-19 minimum.

^f Log walls must comply with ICC400, with a minimum thickness of 5" or greater. All windows in log walls must have an area-weighted average U-factor of 0.31 or less. In addition, the minimum efficiency of gas heating systems is 90 AFUE and 84 AFUE for oil systems.

The primary advantage of using the prescriptive compliance method is that it is comprised of a simple list of performance standards that does not require energy

modeling or calculations to determine whether a home is energy code-compliant. On the other hand, there is very little flexibility associated with this compliance method and in general, the level of stringency associated with the specification is higher than what it might be using the performance-based compliance method.

Note that there are additional considerations for buildings that include steel-framed assemblies and/or mass walls. See IECC 402.2.5 for details.

Table 1.2 below presents the prescriptive specifications for New Hampshire from the new **2012 IECC** for your reference.

Table 1.2 2012 IECC Prescriptive Specifications for New Hampshire

Climate Zone	5	6
Window U-Factor	0.32	0.32
Skylight U-Factor	0.55	0.55
Ceiling R-Value	R-49	R-49
Wall R-Value	20 or 13+5	20+5
Floor R-Value	30	30
Foundation Wall R-Value ^b	15/19	15/19
Slab R-Value & Depth ^c	10, 2 ft.	10, 4 ft.
Crawl Space Wall R-Value	15/19	15/19

Total UA Alternative (IECC 402.1.4)

The total UA for a house is the sum of the values that are produced when the U-factors (U) for all of the individual components of the thermal boundary are multiplied by the areas (A) of those components. A UA value can be used as a simple measure of energy efficiency; the lower the number, the better. If energy calculations can be used to demonstrate a level of energy efficiency that is at least as high as it would be if the prescriptive specifications from IECC Table 402.1.1 were used (i.e., if the calculated UA is less than or equal to what it would have been otherwise), then the building shall be deemed as being energy code-compliant. See Appendix A to learn more about performing UA calculations.

The simplest way to perform UA trade-offs is to use REScheck, an easy-to-use software program that facilitates the compliance process. Using REScheck:

- **Allows significant flexibility** for determining compliance specifications for most situations.
- **Allows the designer to trade off** better performance in one area, like higher R-values of insulation, to offset poorer performance in another, like higher U-factor windows.
- **Requires that you calculate square foot areas** for all insulated components of the building such as walls, floors, ceilings, windows and doors.

- **Is the most forgiving** in the sense that it will be the easiest way to pass the compliance test for most houses.

The software is available for free on the internet at: www.puc.nh.gov. Click on “Energy Codes,” “Residential” and then “Click here to download REScheck software.” Instructions are also available with the software, and context-sensitive help menus are built in.

Some things to remember with REScheck:

- Always start by making sure the appropriate location and code have been selected.
- Use grosswall areas, including all windows and doors. REScheck subtracts window and door area automatically.
- Don’t forget to include band joist areas (except band joists of insulated floors) in the net wall area.
- Use window frame size or rough opening for window area, not the glass or sash size.

Performance-based Compliance (IECC Section 405)

This compliance method is based on a simulated energy performance analysis. Compliance is shown to be demonstrated when the projected, annual energy cost associated with the proposed home is less than or equal to the annual energy cost associated with a theoretical reference home (which is referred to in the code as the “standard reference design”). The parameters for the detailed calculations that must accompany this analysis are spelled out in IECC Tables 405.5.2(1) and 405.5.2(2). The approach is very similar to the one used to generate a Home Energy Rating System (HERS) index (described on page 15). HERS ratings, in fact, are recognized as an acceptable method for demonstrating performance-based code compliance.

The primary advantage of this method of demonstrating energy code compliance is that it allows builders to “trade off” different aspects of a home’s efficiency features to achieve the required level of efficiency (energy cost) without meeting the rigid minimums that are the basis of the prescriptive compliance method. And unlike prescriptive compliance, the trade-offs are not limited to UA equivalencies. The performance-based energy analysis takes into account a much wider range of efficiency features, including – but not limited to – insulation levels, window U-factors, orientation, air infiltration, and service water heating. Although theoretically you could use these trade-offs to eliminate the need to insulate one or more building components or portions thereof, this approach is not recommended. It will result in an unbalanced investment, by requiring overcompensation somewhere else, and an increased potential for comfort or moisture problems due to cold surfaces.

Documentation (IECC Section 103)

Once you have used one of the design tools to determine the specifications of R-values, U-factors and equipment efficiencies for your project, you need to submit

those specifications as part of the building permit application process. When using the performance package, this will consist of submitting a 1 page PUC application, see Appendix C - NH Energy Code Application (EC-1 Form) and Air Barrier and Insulation Inspection Criteria (also available at www.puc.nh.gov, click on “Energy Codes” and then “Residential”). If the software is used, a takeoff worksheet and the REScheck printout must be submitted along with the PUC application. The takeoff worksheet is also available at the PUC web site and is used to summarize the calculations that were performed to determine the areas of all the building components. It’s a good idea to make a copy of the paperwork for each project you submit.

As an alternative to the above, architects and engineers who are registered and practicing in New Hampshire may certify that any blueprint to which they affix their professional seal, meets or exceeds the requirements of the energy code. The certification must be accompanied by a statement that reads, “The proposed structure has been designed and reviewed by the architect or engineer and is determined to be in compliance with all applicable requirements of RSA 155-D and the energy code adopted pursuant thereto.”

Application Submission

In towns with a full-time building inspector, submit the application directly to the town (unless otherwise instructed). In towns with a part-time building inspector or no building inspector, submit applications to the New Hampshire Public Utilities Commission (see Appendix B for contact information). If you are not sure, call the town or the PUC.

Plan Review and Field Inspections (IECC Sections 103 and 104)

Building inspectors will primarily be looking to see that the house meets the general requirements summarized earlier in this chapter, as well as the specifications that you submitted when you applied for the building permit. See Appendix D - IECC Residential Compliance Checklists Zones 5 and 6, for an example building inspector code compliance checklist. As long as the insulation R-values and equipment efficiencies in the house equal or exceed the specifications from the compliance analysis, and you follow the general requirements, you should pass without difficulty. Window, door and skylight U-factors must be equal or less than the U-factors from the analysis. Don’t forget about these issues:

- Insulation must be installed properly (see page 17), and with R-value markings visible.
- The requirements for verifying window performance are on page 17. NFRC rating labels should remain attached to all windows until they are checked by a building code official and/or other third-party inspector(s).
- Requirements for equipment design are on page 17.

Additions, Alterations, Renovations and Sunrooms

Additions

An addition is defined as “an extension or increase in the conditioned space floor area or height of a building or structure.” The thermal requirements for additions can be determined using the same methods (prescriptive and performance-based compliance) described earlier in this chapter. The addition can be analyzed by itself, or the entire building including the addition can be analyzed and shown to be compliant.

Renovations

In general, any renovation or repair that affects the thermal boundary of a building or structure must satisfy the same requirements that would apply to a newly built home or addition. Exposed building cavities, however, only need to be filled with insulation (even if this results in a below-minimum R-value). Storm windows and glass-only replacements (excluding the window sash and frame) also need not comply, provided that the energy use of the building is not increased.

The general requirements of the code, and many of the details in this guide, apply to additions, heated sunrooms and renovations as well as new homes. However, many of the issues regarding moisture, air leakage, movement, etc. require extra attention whenever additions meet the existing building.

Sunrooms

A sunroom is defined as “a one story structure attached to a dwelling with a glazing area in excess of 40 percent of the gross area of the structure’s exterior walls and roof”. If a sunroom addition is open to the existing structure, it must satisfy the same requirements that would apply to a newly built home or addition. If the sunroom is thermally isolated (i.e., it is separated from the conditioned space or the main building or structure by a sealed, insulated wall, door and/or window) and heated, then:

- The sunroom must have either a separate HVAC system, or be served by an HVAC zone that is separate from the rest of the building or structure.
- The minimum ceiling insulation R-value must be R-24 and the minimum wall R-value must be R-13.
- The maximum window U-factor must be 0.50 and the maximum skylight U-factor must be 0.75.
- Any new walls, doors, and/or windows separating the existing structure from the sunroom must meet the associated requirements for the main body of the house.

A thermally isolated sunroom that is not heated does not need to comply with the energy code.

2



ENERGY STAR Qualified New Homes

The ENERGY STAR Advantage

The ENERGY STAR advantage allows builders and developers to increase profitability and market success by building homes with high levels of comfort, indoor air quality, and energy efficiency. Based on an energy efficiency guideline set by the United States Environmental Protection Agency (EPA) and the Department of Energy (DOE), ENERGY STAR Qualified New Homes are nationally recognized for greater value, lower operating costs, increased durability, comfort, and safety.

The New Hampshire ENERGY STAR Homes program is a voluntary program sponsored jointly by the following utilities: Public Service Company of New Hampshire (PSNH), Utili, New Hampshire Electric Cooperative and National Grid. For details on specific rebates and services that may be available to you, visit www.nhsaves.com.

ENERGY STAR Homes Version 3.0

While codes and standard practices have continued to strengthen across the country, EPA has released a third-generation of guidelines (“ENERGY STAR Version 3”) that was phased in during 2011 and will become mandatory in 2012 for program participation.

There are still two paths that can be used to achieve ENERGY STAR qualification for new homes in Version 3:

- 1) Prescriptive, using a predefined package of energy efficiency improvements, **or**
- 2) Performance-based, using the Home Energy Rating System (HERS)

Both options are based on a set of specifications called the ENERGY STAR Reference Design. When the prescriptive path is used, the home is simply built according to the Reference Design specifications (similar to the Builder Option Package approach used in ENERGY STAR Version 2). The Version 3 performance path, however, has been significantly changed from the Version 2 approach. (Note that NH energy programs require participants to use the performance approach). Version 2 relied on a fixed HERS index for the performance path, with 80 being the maximum rating for compliance. ENERGY STAR Homes V3.0 now uses a custom HERS index target that is calculated for each home.

In addition to the baseline requirements specified in the Reference Design, there are new checklists with detailed mandatory requirements for Thermal Enclosures, HVAC Quality Installation, and Water Management.

- The Thermal Enclosure checklist to ensure that there are no thermal defects.
- The HVAC Quality Installation checklists to ensure that HVAC systems are installed using industry best practices and perform at rated efficiencies.
- The Water Management builder checklist to ensure roofs, walls, and foundations are fully protected from water intrusion.

Builders, raters and HVAC contractors must also complete specific training requirements to be eligible to participate in Version 3.

Benchmark Home Size

Homes of all sizes can be ENERGY STAR qualified; however homes that are larger than their Benchmark Home Size must have a Size Adjustment Factor applied. The Benchmark Home Size is based on the number of bedrooms in the home to be built. Follow the steps below to determine if size adjustment factor applied.

1. Count the number of bedrooms in the home and calculate the conditioned floor area. Bedrooms and floor area in basements with at least half of the gross surface area of the basement's exterior walls below grade are not counted.
2. Subtract any bedrooms and floor area in basements that have at least 50% of their exterior wall area below grade.
3. Use the resulting number of bedrooms to compare the Benchmark Home Size against the comparison area of the home to be built.
4. If the comparison area of the home to be built is larger than the Benchmark Home Size, the home must have the Size Adjustment Factor applied.

Benchmark Home Size

Bedrooms	1	2	3	4	5	6	7	8
Conditioned Floor Area	1,000	1,600	2,200	2,800	3,400	4,000	4,600	5,200

Alternative Performance Path (HERS)

An alternative performance path provides flexibility to select a custom combination of measures for each home that is equivalent in performance to the minimum requirements of the ENERGY STAR Reference Design Home. The basis of this compliance option is a HERS rating, which is an energy analysis similar to the “Systems Analysis” compliance path for the energy code (see page 7). A HERS rating is a nationwide standard that is used to rank the efficiency of a home. This ranking, or index, is from 100, which corresponds to a home that is built to meet the requirements of the 2004 International Energy Conservation Code (IECC), to zero, which corresponds to a very efficient, “net zero” energy home.

Using the Version 3 performance path, the home is modeled using the ENERGY STAR Reference Design specifications to establish an Initial HERS Index Target Score. For larger homes, a Size Adjustment Factor (SAF) is applied to the Initial Target Score when the home exceeds the defined ‘Benchmark Home Size,’ based on the number of bedrooms. The builder then has the flexibility to select a custom set of energy-efficiency measures, so long as the resulting HERS Score for the home meets or performs better than the HERS Index Target Score (size-adjusted, when appropriate) and all other requirements are met (e.g., minimum efficiency for windows, insulation levels).

The primary advantage of a performance path is that it allows a builder to “trade off” aspects of a home’s efficiency features to achieve a target without needing to meet every element of a rigid minimum standard, thereby adding flexibility to the design process.

The most important aspect of this compliance option is the overall level of energy efficiency, not the strategy that is used to achieve that level. Accordingly, strengths in one part of a home’s design (e.g., high efficiency windows) may be used to offset relative weaknesses (e.g., lower insulation levels) in another part of the design. In addition to demonstrating compliance via a HERS rating, every home must meet the Mandatory Requirements for All Homes.

Mandatory Requirements

Training Requirements

Builders must complete the online ENERGY STAR Orientation Training to be eligible to build homes qualified under Version 3. Verification partners, including HERS raters and Field Inspectors, must complete ENERGY STAR

Version 3 Rater Training through an Accredited Training Provider. To be eligible to install HVAC equipment in homes qualified under Version 3, HVAC contractors must complete ENERGY STAR Version 3 Training and be credentialed through an EPA-recognized industry organization.

Thermal Enclosure Checklist

The Thermal Enclosure Checklist is a list of mandatory, energy efficient building practices that must accompany both the performance-based and prescriptive compliance paths. This list, formerly known as the Thermal Bypass Checklist, was developed to ensure the continuity and effective performance of a building's thermal enclosure, and has been expanded in ENERGY STAR Version 3. It addresses a wide range of practices that includes—but is not limited to—properly enclosing insulation, protecting insulation from wind washing, sealing voids and chases in the insulated attic plane, and identifying and sealing other bypasses that are commonly hidden in the building frame. All the items on the checklist must be verified as having been completed before a house can be ENERGY STAR qualified.

Many states also supplement the national ENERGY STAR standards with minimum requirements for other building components or other elements of building performance. New Hampshire is no exception. All of the program implementers in New Hampshire have supplemental requirements for, among other things, whole-house mechanical ventilation. Check with a program representative for details.

The Thermal Enclosure Checklist incorporates the air barrier and air sealing components from Version 2.0, with the addition of three new sections. The New Thermal Enclosure Checklist incorporates the following sections:

Section 1 High Performance Windows – Fenestration must meet the IECC 2009 requirements.

Section 2 Quality-Installed Insulation – Insulation must meet RESNET Grade I quality or Grade II if insulated sheathing is installed.

Section 3 Fully-Aligned Air Barriers – At each insulated location, a complete air barrier must be provided that is fully aligned with the insulation.

Section 4 Reduced Thermal Bridging – Advanced framing techniques must be used to reduce thermal bridging in walls.

Section 5 Air Sealing – Joints, seams and penetrations to unconditioned spaces must be fully sealed with solid blocking or flashing as needed and gaps sealed with caulk or foam

Download the Thermal Enclosure System Rater Checklist Guidebook from www.energystar.gov for more details.

HVAC System Quality Installation Checklist

In the new ENERGY STAR Homes Version 3 guidelines, HVAC systems must be installed according to industry-accepted Quality Installation (QI) guidelines established in ANSI/ACCA Standard 5 QI. This Standard establishes best practices for proper installation of HVAC systems for optimal performance, providing homeowners with comfort, efficiency, and savings. The four main requirements of an HVAC QI are:

1. Proper equipment sizing and component matching;
2. Correct refrigerant charge;
3. Proper airflow to match refrigerant capacity; and
3. Sealing ducts to minimize leaks.

To ensure that HVAC systems in ENERGY STAR qualified homes are installed properly, the HVAC contractor will be required to complete and sign a detailed inspection checklist based on the QI Standard. An independent Home Energy Rater will also review the contractor's checklist and validate key data points for accuracy.

Download the HVAC Quality Installation Rater Checklist Guidebook from www.energystar.gov for more details.

Water Management System Checklist

The Water Management System Checklist is designed to help improve moisture control in new homes. This checklist must be completed by the builder and verified by the rater. The checklist provides detailed specifications for the installation of flashing, capillary breaks, drain tiles, and moisture-resistant materials in four major areas:

1. Site and foundation
2. Wall assembly
3. Roof assembly
4. Building materials

Download the Water Management System Rater Checklist Guidebook from www.energystar.gov for more details.

Other considerations

Builders who build ENERGY STAR Qualified New Homes reap the benefits of:

- Increased profits
- Increased customer satisfaction
- Differentiation in the marketplace

For most builders, the upgrade to building an ENERGY STAR Qualified New Home is relatively small, especially if they are already exceeding minimum code requirements. One advantage of the performance-based compliance

option is that it accounts for the benefits of efficiency features that are beyond the scope of the energy code (e.g., solar gain from south facing glass, a tighter building enclosure, and high efficiency water heating).

For more general information about New Hampshire's ENERGY STAR for New Homes Program, visit the web site at www.nhsaves.com.

How do I certify my new home?

Any house can be constructed to ENERGY STAR levels, no matter what the style. The ENERGY STAR process is easy to incorporate into your construction timetable. Here's how it works:

- **Choose a program implementer**/accredited HERS provider (see Appendix B, page 145) to guide you through the qualification process.
- **Submit a set of blueprints**, along with any other paperwork that might support a detailed energy analysis. A HERS Rater will analyze the plans and, if necessary, propose upgrades to bring the home to ENERGY STAR levels. The rater will work with the designer, builder, and/or client to determine the final specifications for each project. Once everyone has agreed on an upgrade package, the rater will issue a list of project specifications, along with any program specific documentation or forms. An energy code compliance report may also be issued at this time.
- **Inspections**—Completion of four inspection checklists is required. These inspections will be performed by a HERS rater or qualified technician. Every home qualified under Version 3 must complete the following checklists:
 - Thermal Enclosure System Rater Checklist
 - HVAC System Quality Installation Rater Checklist
 - HVAC System Quality Installation Contractor Checklist
 - Water Management System Builder Checklist
- **Certification**—Once the final inspection is complete, the rater will issue the final energy rating, and your home will be labeled as an ENERGY STAR Qualified New Home!

The HERS Rater will help take you through the entire process: he or she will suggest cost-effective improvements or money-saving trade-offs, help you with energy code documentation, and ensure that energy details are done correctly, from the plans stage through the finished product.

3

House System

Moisture related failures, indoor air quality problems, combustion backdrafting, sooty "ghost" stains on walls and carpets, mold and mildew in homes—callbacks of these types have increased dramatically in recent years. They are often blamed on houses that are "over-insulated" or "too tight." Although these problems were unusual in the days when houses were leaky and uninsulated, they are not caused by these factors alone. In fact, it is rare to find a failure of this sort which is caused by any single factor. These problems are usually the result of the different components of the house interacting, as a system, in ways that were not foreseen by the builder or designer.

Over the last century, the introduction of new materials such as plywood sheathing and housewraps has changed the way houses are built. Houses are tighter, and there are many more pollutants found inside, generated by the occupants and by the building materials themselves. As energy costs have risen, insulation has become a necessity. The advent of central heating systems with automatic controls has contributed to increased consumer demand for comfort in their homes, and heating systems have become more efficient. In addition to advances in building construction, consumer lifestyle changes have altered homeowners' expectations. People want houses that are larger and more complex, with more features than ever before. All of these things have an effect on each other, and on the operation of the house system.

It is becoming widely recognized that many of the failures and warranty callbacks in new houses are a result of misapplying new technologies or materials—not because they were installed "wrong," but because nobody predicted the effect that a change in one area might have on some other part of the house. Often, the complexities of a building make it difficult to find the source of a problem, even after it occurs. Consider the following example (a true story):

Building Failure Case Study

A homeowner calls in a building science specialist to help with a moisture problem during the heating season. The house has condensation and mold in the attic and living space. The specialist arrives at the property, and an interview of the client shows that this is an ongoing problem; in fact, it has gotten worse. The customer had previously consulted with several contractors and the local utility company, and was informed that the solution to the moisture in his attic was to add ventilation. When he asked how much ventilation to add, he was told, "You can't over-ventilate an attic." He was also warned that soffit vents would do him no good if they were blocked by insulation. So he installed extra soffit ventilation and pulled the insulation back from the eaves to allow free air flow. Since the hip roof did not have much ridge area, the homeowner installed two turbine vents to satisfy the need for upper ventilation.

On inspecting the house, the specialist finds the following:

- The roof sheathing is damp and spotted with mold.
- The roof has continuous soffit vents and two turbine vents.
- The fiberglass batts in the attic have been pulled away from the eaves approximately 18".
- There is black mold growing on the second floor ceilings in rectangular patterns around the house perimeter.
- The relative humidity in the living space is measured to be higher than normal for winter conditions.
- The bathroom exhaust fans are vented outdoors, but have a very low air flow rate and are rarely used.
- A blower door test confirms that the building is fairly tight, but there is still communication between the attic and the living space, by means of top plates and an open plumbing chase.
- The clothes dryer in the basement has a vent to outside, but the hose is disconnected.
- There is a piece of plywood in the basement loosely covering a sump, which leads to a small stream running underneath the building.

It is clear to the specialist what has happened. First, the turbine vents drew air not only through the soffit vents as intended, but also drew more air than ever from the house into the attic. With the high levels of humidity in the living space, combined with the fact that leaks into the attic had never been sealed, the turbines were moving moisture into the attic even more quickly than before. Second, in his effort to open up the soffit vents, the homeowner removed the insulation. This created a cold surface all around the perimeter

of his upstairs ceiling for moisture to condense, and mold to grow on. No one thought to look in the basement when diagnosing the problem, but this is where the source of the moisture was lurking all the time.

The specialist wrote up a repair punch list as follows:

- Cover the sump in the basement with a gasketed cover to discourage the water from evaporating into the house.
- Re-connect the dryer hose.
- Seal leaks into the attic, to minimize the path for moisture to reach the attic.
- Replace the turbine vents with standard roof vents.
- Re-insulate the perimeter of the attic.
- Install baffles to allow free air movement through soffit vents and to direct the air over, rather than through, the insulation.
- Install a continuous running, low-level exhaust fan in one bathroom, to ensure the proper ventilation rate.

When the building was inspected the following year, the moisture was gone and the occupants were healthier and more comfortable.

Why did this building fail? The answer lies in the fact that nobody evaluated how one aspect of the building's construction might affect another part of the building. Additionally, nobody evaluated the effects of occupant behavior on the performance of the building. When the foundation was built, it was noted that the underground water might cause flooding problems, so the decision was made to include a sump. When the framing, exterior shell, and interior finish were installed, each contractor took enough care that the building ended up with a relatively air-tight shell. But the builder did not realize that by doing these two things successfully, they had created a highway for moisture to pass through the interior wall cavities directly from basement to attic. Bathroom fans were installed and properly vented outside, but nobody predicted that the occupants wouldn't use them.

Why was the moisture problem misdiagnosed? This is primarily because the contractors making the assessment took too narrow a view when evaluating the house. If a problem occurs in the attic, it is easy to assume that you will find the answer by looking in the attic. However, the house system is complex enough that this is often not the case.

The House as a System

When one component of the building fails, or is even out of tune, it can set off a chain reaction with unexpected results. To successfully avoid these kinds of failures, it is necessary to take a systems approach to the design and construction of buildings. Every trade may do its job properly, but if nobody is paying attention to the issues of moisture sources and ventilation, a house can end up with serious mold and mildew problems. Every aspect of a home may meet the required codes, but there can still be carbon monoxide spillage into the living space. The construction supervisor may do a fine job of managing all the subcontractors, but if no one considers the interactions of the individual parts of the building, or thinks about how the building will perform when occupied, all this hard work may be inadequate.

It is easy to look at the house as a collection of components: foundation, frame, mechanical services, drywall, trim, fixtures and finishes. But there is more to a building than this. Figure 3.1 shows a schematic of the house system with some of its interactions.

The first step to understanding the house system is to realize that the building structure itself, and the mechanical systems in it, interact with each other and with the people in the building. People turn thermostats up and down, they move switches and valves, they build walls, cut holes, and leave windows and doors open or closed. Both the building and the mechanical systems also interact with the immediate environment around the house: how cold or hot is it, which direction is the sun shining from, how much wind or rain. These environmental factors change the building directly, causing parts of it to get hot or cold, or to get wet, and to dry out; and they also affect how comfortable people are inside, causing them to act in different ways relative to the building.

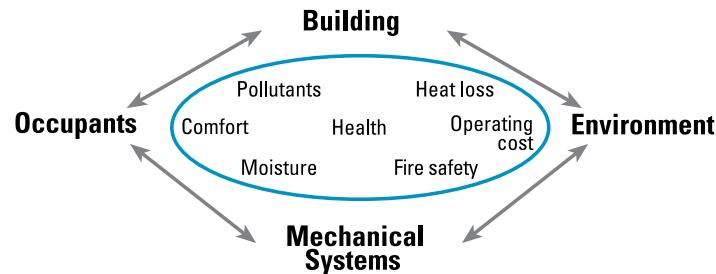
It is not necessary to make a study of every interaction that can happen in a building based on this concept. However, it is important for someone to take responsibility for the house as a whole system, and to think about common ways that the components in a house interact under everyday situations. It is imperative that house designers and general contractors learn the basics of the house as a system if they want to avoid these problems.

Fortunately, there has been much research in recent years and a growing body of field experience based on new construction, testing, weatherization and remediation work. Ice dams, indoor air quality problems, radon, nail pops in drywall, freezing pipes, combustion safety and backdrafting problems can all be reduced by understanding the basics of moisture and air movement. These effects can be understood on a level sufficient to avoid the most common problems, as long as someone is thinking past the individual parts and looking at the whole.

Going Further

This guide attempts to include details that are consistent with good building science as well as applicable codes. However, it is beyond the scope of this guide to address the subjects of moisture and air movement in much detail. Many of the sources listed in Appendix B contain excellent information on building science and house system interactions. The EEBA Builder's Guide has more detailed information on building failures, along with their causes and solutions.

FIGURE 3.1
The House as a System



4

Planning

This chapter gives designers, general contractors, and builders guidance on what energy-related issues are best resolved before breaking ground. In addition, guidelines for ensuring that the house complies with the energy code right from the beginning are provided. Whether the house is designed by an architect with help from engineers, or by an owner-builder, good planning pays off with systems that work well together.

Energy Code Requirements

The designer or builder of a new home is responsible for designing a home that will meet the energy code. To determine minimum insulation R-values and window U-factors, choose and complete one of the compliance methods listed on pages 7-10. Also see Appendix C. Performing the compliance analysis early in the planning process has several benefits:

- The thermal performance of various components can affect the detailing; the R-value of walls and cathedral ceilings, for example, can have an impact on the thickness of those assemblies.
- It is much easier to make adjustments to the design based on energy code constraints before the design has been finalized.
- As the designer, it may be faster for you to calculate the square foot areas of the various components to show code compliance.

As you develop specifications for subcontracted work, specify the energy performance standard (where applicable) indicated by the energy code compliance analysis. It is also a good idea to build some “cushion” into the specifications (i.e., create a margin of safety in complying). That way, if the client decides to make a change that will impact the analysis (like adding a window during the construction process), the house is more likely to remain compliant.

Other energy code-related considerations are highlighted within the text of the remaining portion of this chapter.

The Thermal Boundary

The thermal boundary is the collection of insulated and sealed floors, walls, and ceilings in the building that separate conditioned spaces from both unconditioned spaces and the outside (see Figures 4.1 and 4.2). A well-detailed boundary is one of the most critical aspects of a high performance home, affecting not only its energy efficiency, but also its durability and occupant comfort. Unfortunately, decisions relating to the placement and detailing of the thermal boundary are often made on the fly. Frequently (and regrettably) the concept of a thermal boundary is not even considered as part of the design and construction of a home; insulation is installed where the insulation subcontractor thinks it should be installed and there is little, if any, conscious effort devoted to air sealing. A thermal boundary should be integrated with the design of all homes. Deliberate decisions about its placement and the materials that will be used to create the boundary are an important part of this process. There are two primary components to the thermal boundary: The first (insulation) resists conductive heat transfer. The second (air barrier) resists air flow. You should ensure that these two components are aligned with one another and installed continuously around the entire volume of conditioned space. In a set of drawings, one or more sections can be used to effectively convey this information. Unfortunately, there is sometimes a disconnect between what is laid out in a set of plans and what is actually constructed in the field. For the thermal boundary, this disconnect can be remedied by complementing plans/specifications with the following guidelines:

- Make sure the general contractor and all subcontractors understand the design associated with the thermal boundary, and the importance of seeing the design through to completion.
- Facilitate implementation by having the necessary materials on site before they are required. Drywall and insulation, for example, may be required before a shower-tub assembly is installed (see Figure 11.8).
- Require all subcontractors to seal any penetrations they make through the thermal boundary. Provide them with the materials they may need, or alternatively:
- Assign someone (typically on the builder's crew) the responsibility of making sure that the integrity of thermal boundary is maintained through every stage in construction.
- Perform a final air sealing check before insulation is installed.

Design Elements

The following is a rough outline of the construction process, paralleling the sequence of upcoming chapters. In each section, considerations that are unique to the planning phase are addressed. Some of the considerations relate to energy code compliance and some of them relate to ENERGY STAR compliance. Many relate to both.

Foundation

The treatment of a foundation wall depends on whether or not it encloses a conditioned space. Conditioned space is defined as an area or room within a building that is finished, or unfinished with an HVAC supply (or other intentional heat source).

- If the foundation encloses a conditioned space, the foundation walls must be insulated. There is a right way (see Figures 5.4-5.6, 5.11) and a wrong way (see Figure 5.3) to insulate foundation walls; this portion of the home should be designed accordingly.
- If the foundation does not enclose a conditioned space, the insulation must run across the floor above the basement or crawlspace instead (see Figure 5.7).

There is a growing consensus among many in the energy efficient building industry that it is preferable to condition basements and crawlspaces. Planning for a conditioned basement or crawlspace offers the following advantages:

- It is easier to install continuous, uninterrupted air and insulation barriers along foundation walls than it is to install them as part of the floor assembly (which is obstructed by framing, pipes, wires, ducts, etc.) The foundation wall is often the better air barrier to begin with.
- It is easier to control the temperature, humidity, and comfort levels in a space that is enclosed by insulation and an air barrier.
- Mechanical and distribution systems are often installed in the basement or crawlspace, and they perform better in conditioned spaces.
- Many homeowners will eventually finish and use the basement space. If they install insulation poorly or are not informed about potential moisture issues, they are much more likely to create moisture and mold problems for themselves later on.

On the other hand, a conditioned basement or crawlspace may:

- Cost more to build. Even without factoring in slab insulation, the area of foundation walls is often greater than the area of the floor they enclose. Insulation that is exposed to the living space also needs to be protected from fire (by installing a code-approved barrier such as 1/2" gypsum board).

- Create a hidden pathway for insect entry (see page 45) and require protection of above-grade surfaces (if the insulation is installed on the exterior surface of the foundation, (see Figures 5.6 and 5.11).
- Increase the need to focus on moisture control. It is especially important to build elements of moisture control into the design of a building that will include a conditioned basement (see page 34 and Figures 5.1-5.2).

Framing

In enclosed building cavities (e.g., walls and cathedral ceilings), the amount of insulation that can be added is limited by the framing depth. If the framing depth is not sufficient to accommodate the minimum amount of insulation required (by energy code or ENERGY STAR), the following options should be considered:

- Specify an insulation product that has a higher R-value per inch (see Table 4.3). High density fiberglass batts, for example, can be used to increase R-values where space is limited; they are also much easier to work with and install correctly. Some rigid board and spray foams can provide R-values as high as 6 per inch!
- Plan for a continuous layer of (rigid foam) insulation that is applied over the framing. Using continuous insulation is the best way to improve the effective R-value of an insulated assembly (see Figure 12.2). A 2x4 wall with 2" of rigid insulation, for example, will outperform a 2x6 wall with cavity insulation without affecting the depth of window and door openings. The 2012 IECC requires that above grade walls in Climate Zone 6 have a layer of continuous insulation.
- Use deeper framing. This is usually the least cost-effective option.
- Use a different compliance method and/or compensate for R-value limitation by improving performance in other areas (e.g. lower window U factor)

Energy savings associated with framing can also be achieved by using details that (1) require less wood and leave more room for insulation (see page 60 and Figures 6.9-6.10), and (2) include provisions for air sealing (see Figures 6.1, 6.2, 6.4 and 6.11-6.17).

Windows

Window type, quantity, orientation, and shading all play a significant role in determining the energy use of a home. Energy use can be minimized by orienting a home in such a way that most of the windows face south. South-facing windows capture heat from the winter sun but do not contribute as significantly (and undesirably) to heat gain in the summer when the sun is much higher in the sky. By contrast, east- and west-facing windows account for more heat gain in the summer than winter. It is preferable, therefore, to orient the long axis of a building east-west if possible. On the south side of the home, overhangs can be provided to allow for solar gain in the winter and to provide shade in the summer. On the east and west sides of the home, mature trees can provide shade. Regardless of orientation, high performance windows with low U-factors should be specified (see page 78 and Figure 7.2). In New Hampshire, the need for heating can be reduced significantly and the need for air conditioning can be eliminated entirely by making smart choices with respect to window type, orientation, and shading.

Despite recent advances in window technologies, windows should still be viewed as weak spots in the thermal boundary (i.e., they allow for rapid transmission of heat from one side of the wall to the other). Performance-based compliance with energy code and ENERGY STAR standards is quite sensitive to the size and number of windows in a house. The more window area, the more difficult it will be to demonstrate compliance. This often results in having to push the efficiency of other building components (insulation R-values) to higher levels.

Mechanical Systems

Placement is one of the most important considerations with respect to designing a mechanical system. A designer usually has little control of the quality of mechanical installations, but they can influence their placement. Heating and cooling equipment, including the distribution system (ductwork or hot water pipes), should be located within the thermal boundary. Ducts that are not located within the thermal boundary are required to be insulated and tested for air leakage.

Duct leaks that occur outside the thermal boundary can cause thermal, comfort, moisture, and backdrafting problems. Resist the temptation to use the wide open space of an unconditioned attic to "house" mechanical and distribution systems. Interior 2x6 walls, soffits, and floor trusses can all be used to facilitate the installation of mechanical systems within conditioned spaces. Consider planning for the space requirements for the mechanical systems and specifying them on the plans.

Heating and cooling systems tend to be substantially oversized, even in

conventionally built houses. If the HVAC installer uses the same rules of thumb to size equipment for an efficient house, they will be even more oversized. Oversized equipment costs more to install and to operate. You can save money on a project by sizing the heating and cooling systems properly (both equipment and distribution systems). These savings can help pay for the upgrades to the building shell. Heating and cooling systems must be sized in accordance with ACCA Manual S, based on building loads calculated in accordance with ACCA Manual J.

To promote efficiency and to eliminate the risk for backdrafting, sealed combustion heating systems and hot water heaters should be specified (see page 85). There are additional cost savings if a chimney can be eliminated as a result. Note that combustion flue gas venting options vary according to fuel type. (See Table 4.1 on page 34.)

A distribution system must also be determined during the planning phase. Again, there are numerous options and related considerations. (See Table 4.2 on page 35.)

Ventilation

Nearly all new homes include some form of mechanical ventilation. A system that is intended to promote good indoor air quality, however, is rarely part of the design. An energy efficient home is an airtight home; an airtight home needs adequate, controlled ventilation. This line of thought is often expressed as “Build tight; ventilate right”. Ventilating “right” may lead you to adopt different strategies in different homes. Use the answers to the following questions to help you decide what will work best for the project you are working on:

- How big is the house? Large houses, especially those with high ceilings, have a greater volume of air to dilute pollutants. Small houses, especially those with several bedrooms, often require the most aggressive ventilation strategies.
- How many people will live in the house? More people will require more fresh air.
- What is the layout of the house? Relatively open, compact houses can be ventilated more effectively from a single point. Sprawling houses and two-story homes benefit more from distributed ventilation.
- How important is fresh air to the owners? Everyone needs fresh air, but some people value it more highly than others. If the owners need or expect very good indoor air quality, you should obviously plan for a system that will provide the desired result.

If you’re thinking about building an ENERGY STAR Qualified New Home (and even if you’re not), you should review the systems that are discussed in Chapter 9 and plan on incorporating one of them into your HVAC design. Whole-house mechanical ventilation is required for any home seeking ENERGY STAR Home certification in New Hampshire.

The 2012 IECC requires that all buildings be provided with whole-house mechanical ventilation.

Plumbing and Electrical

Pipes and wires that run through insulated assemblies create leakage pathways and insulation voids that compromise thermal performance. Just as with mechanical systems, plumbing and electrical components should be installed within conditioned space, and associated penetrations through the thermal boundary should be minimized and sealed. Consider planning for the space requirements of these building elements and specifying them on the plans.

Additional energy (and water) savings can be achieved by laying out the plumbing components in a sensible manner (e.g., installing a hot water tank in close proximity to the kitchen/bathrooms). See Chapter 10 for an overview of related recommendations.

Lighting and Appliances

A minimum of 50 % of the lamps in permanently installed lighting fixtures must be high-efficacy lamps. Recessed lights in insulated ceilings must be rated for Insulation Contact (“IC” rated), and must be airtight as outlined in IECC 402.4.5. Choose units with a label that references ASTM standard E 283, MEC, IECC, or that are “Washington State’s Compliant”. This requirement can also be satisfied by installing sealed, airtight boxes over recessed lights.

For ENERGY STAR requirements, see table on page 104. For more information about energy efficient lighting, visit www.energystar.gov, click on “Products,” and go to *Find ENERGY STAR Products*.

The 2012 IECC requires a minimum of 75% of lamps in permanently installed fixtures to be high-efficacy and prohibits continuously burning pilot lights on fuel gas lighting systems.

Air Sealing

Air sealing is one of the most important aspects of energy efficient construction. Homes that are not consciously air sealed at key stages during construction rarely perform well. Adopt a proactive approach to air sealing. Important guidelines for adopting such an approach are outlined in the “Thermal Boundary” section of this chapter (see page 26).

In general, simple shapes are the easiest to seal. Many new homes are expansive and have designs that feature complex geometries. In these homes, pay extra attention to identifying and treating attic bypasses, framing transitions, and other potentially significant sources of air leakage (see Chapter 11). Also consider locating the thermal boundary where there is the greatest likelihood of achieving a continuously air sealed barrier (e.g., the roof instead of the ceiling; see Figures 6.15-6.17).

Insulation

Specify insulation products that are easy to install correctly, and that are appropriate for the unique characteristics of the assembly to be insulated (see Table 4.3). Rigid or spray foam, for example, are better choices for insulating foundation walls than fiberglass or cellulose (see Figures 5.3-5.6). Spray foams may be more appropriate for complex cathedral ceilings. Loose fill or blown-in insulation is more appropriate in flat attics. Some types of insulation, such as dense-packed or damp-spray cellulose, or spray foams, fill cavities completely, help to reduce air leakage, and add more R-value in the same sized framing cavity. Rigid foam applied to the exterior walls and/or ceilings not only adds R-value, but also reduces the thermal “bridge” of the framing, can form a good air barrier if the seams are sealed, and provides condensation resistance. Think about specifying some of these materials to improve the performance of the building.

Plan for Success

Good planning is important for good buildings, but good planning does not guarantee good buildings. Many building plans are drawn with exemplary construction details, and those details are ignored, botched, replaced, or omitted by “value engineering,” before or during the construction process. Subcontractors often complete their jobs without consulting plans and without giving any consideration to how their work might affect other subcontractors. Similarly, general contractors who are not committed to the “house as a system” approach to building may not see the project through in a seamless, integrated fashion. No matter how it is defined, success will be unlikely in these cases.

Careful planning must be complemented by effective communication, teamwork, and testing. The designers on the front end of a project (architects, engineers) must work with the builder and subcontractors at the back end, and vice versa. A home energy rater or other energy consultant, acting as an independent third party, can also help to verify home performance (by performing visual inspections and testing) and can offer guidance from the design phase through to project completion.

Table 4.1 Heating fuel characteristics

Fuel Type	Venting Options	Other Considerations
Home Heating Oil	<ul style="list-style-type: none"> Best vented through a chimney Direct vent available, but requires careful design and installation Combustion air kits available for some equipment 	<ul style="list-style-type: none"> Inexpensive fuel; high heat content Low-output equipment not as common; hard to find right-sized equipment for low-energy homes Fuel must be kept warm Flue gases should not be allowed to condense in heat exchanger or vent
Liquid Propane	<ul style="list-style-type: none"> Can be chimney or direct vented Sealed combustion appliances common 	<ul style="list-style-type: none"> Equipment must be cleaned periodically Usually the most expensive fuel; lower heat content per gallon than oil Modulating burners can vary heat output Higher efficiencies and reduced maintenance (most natural gas equipment is available in an LP version) Suitable for small, tight, energy efficient buildings
Natural Gas	<ul style="list-style-type: none"> Can be chimney or direct vented Sealed combustion appliances common 	<ul style="list-style-type: none"> Wide range of equipment available; suitable for most homes. Modulating burners can vary heat output
Wood/Biomass	<ul style="list-style-type: none"> Best vented through a chimney Direct vent available in electric pellet stoves Combustion air kits available for some new stoves 	<ul style="list-style-type: none"> Cord wood and wood pellets less expensive than oil Relatively high efficiency

Table 4.2 Distribution system options

Distribution Type	Considerations
Ducts (forced air)	<ul style="list-style-type: none"> Usually the least expensive option, but the most prone to installation defects (poor sealing and/or insulation) which can dramatically reduce system efficiency Often paired with a furnace and/or air conditioning system. Boiler can also be used as heat source by installing hydro-air handler Long duct runs and/or poorly installed (undersized, improperly balanced) ducts can seriously reduce heat delivery and occupant comfort levels Ducts can be used to facilitate distribution of fresh air (by integrating mechanical ventilation system) Air handler can account for significant amount of electrical energy use; choose ECM motor to save electricity
Hot water baseboard	<ul style="list-style-type: none"> Can only be paired with boiler or hot water heater Must be sized according to the heat/cool loads, water temperature, and rated output. Easier to divide distribution system into several zones
Hot water radiator	<ul style="list-style-type: none"> Same consideration as above Saves space compared to baseboards or ducts
Radiant floor	<ul style="list-style-type: none"> Most expensive distribution system, but typically associated with highest comfort levels Should be paired with condensing boiler for maximum efficiency Radiant tubes can be embedded in concrete slabs (including thin, lightweight concrete slabs that can be applied to framed, wood floors) or can be secured to the floor from below. Typically a poor match for a passive-solar heated slab floor; may not be a good investment in a very energy-efficient home
No distribution (space heater)	<ul style="list-style-type: none"> Can adequately heat small, energy efficient homes that have a relatively open floor plan.

Table 4.3 Insulation Properties¹

Form	Method of Installation	Where Applicable	Advantages	Notes
Product(s) — (R-value per inch) ²				
Blankets, Batts or Rolls	Fitted between studs, joists and rafters	All wall, floor, and ceiling cavities prior to hanging drywall	Inexpensive and readily available	<ul style="list-style-type: none"> Only suited for standard stud and joist cavities that are relatively free from obstructions. Prone to installation defects which can dramatically reduce effectiveness of insulation (see Figure 12.2). High-density fiberglass batts (e.g., R-21 batts for 2x6 walls) provide a higher R-value per inch and are easier to install properly.
Fiberglass — (3.1-3.7, depending on density)				
Rock Wool — (3.3)				
Loose-fill (blown-in)	Blown into place using specialized equipment (hopper, blower and hoses)	Enclosed building cavities and unfinished (open) flat attics	Fills gaps and voids typically found in irregularly shaped spaces and around obstructions.	<ul style="list-style-type: none"> Must be protected from "wind washing". To avoid settling, insulation should be installed according to manufacturer's instructions. R-value depends on density (number of bags per square foot), not thickness. Dense pack cellulose has a slightly reduced R-value per inch. Must be protected from "wind washing".
Rock Wool — (3.0)				
Fiberglass — (2.0 -2.5, depending on density)				
Cellulose — (3.5 - 3.7, depending on density)				
"Dense pack" cellulose				

Form	Method of Installation	Where Applicable	Advantages	Notes
Product(s) — (R-value per inch) ²				
Spray Applied	Same as above. A fine mist of water is applied simultaneously to make cellulose "stick"	Open wall cavities prior to drywall	Same as above	<ul style="list-style-type: none"> Cost effective alternative to fiberglass batts. Requires some drying time before interior wall sheathing is installed.
Cellulose — "damp" - (3.5)				
Spray Applied	Chemical components stored in separate containers, mixed in nozzle at end of hoses	All wall, floor, and ceiling cavities prior to hanging drywall	Provides excellent fit and air barrier	<ul style="list-style-type: none"> Vapor permeance and price vary according to density. High density foam has a perm rating of less than 1 and is more expensive; low density foam has a perm rating of about 10-15 (at 5" thick) and needs an added vapor retarder. Significant waste can be generated when excess foam is "shaved."
Polyurethane Foam — (3.4 - 6.0, depending on density)				
Rigid Insulation - Foam	Cut to fit into building cavities or (preferably) over framing. Can also be applied directly to concrete (interior or exterior; see Figures 5.4 - 5.10)	Slab floors, foundation walls, above grade walls, ceilings, and roofs	High R-value per inch. Significantly improves thermal performance when used as continuous, uninterrupted layer of insulation	<ul style="list-style-type: none"> For fire safety, interior applications must be covered with 1/2-inch gypsum board or other building code-approved material Exterior applications must be covered if exposed to sunlight.
Extruded polystyrene (XPS) — (5.0)				
Expanded polystyrene (EPS or bead board) — (4.0)				
Polysiocyanurate — (6.0)				

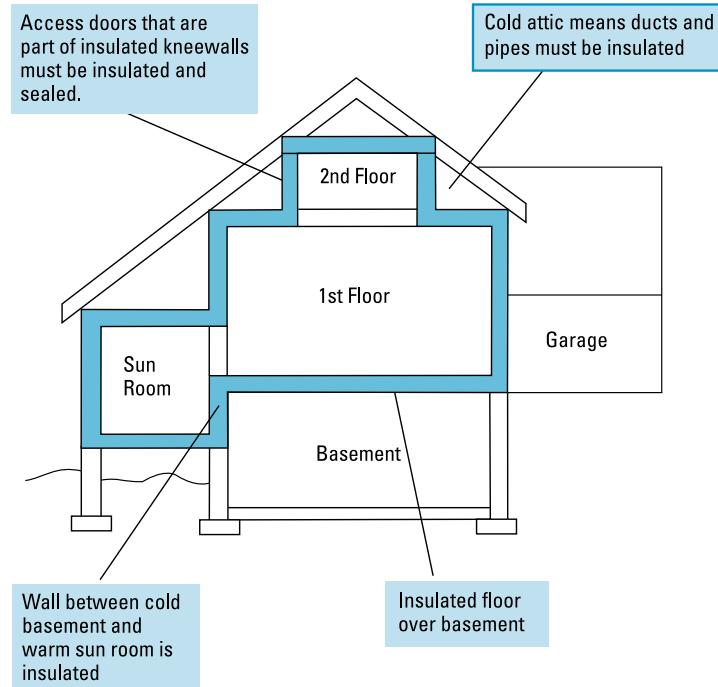
¹ Table adapted from Department of Energy, DOE/CE-0180 (with Addendum 1, October 2002

² Conservative estimates provided for use in absence of better documentation. In order to achieve listed R-values, insulation must be installed (1) according to manufacturer's instructions and (2) without any voids, gaps, or compression. Common installation practices vary by product and installation defects can significantly reduce the effective R-value.

3 In any case seek the advice of your building and/or fire code official about fire ratings on insulation when appropriate

FIGURE 4.1

Typical Cape with unconditioned basement

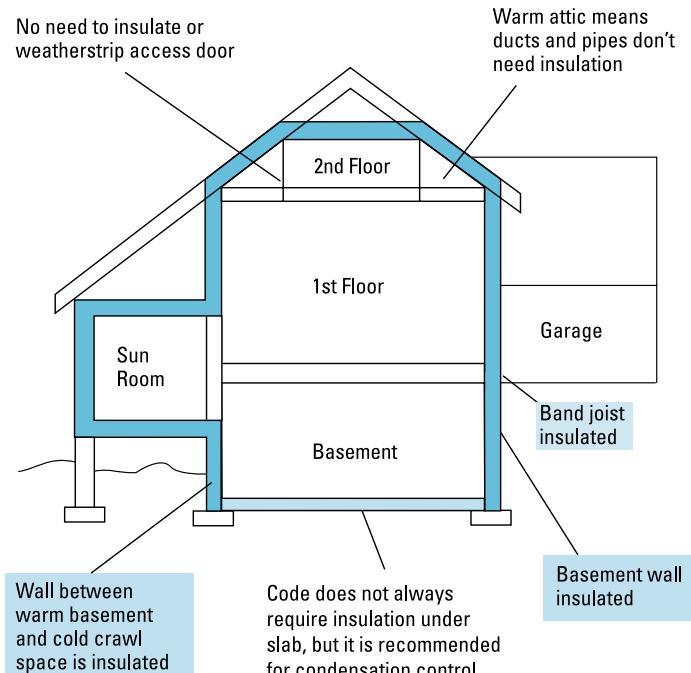


This is a schematic of a Cape style house with an unconditioned basement and unheated kneewall areas.

Tuck-under garages and attached garages are especially important to seal and isolate from the rest of the house, not only because of heat loss but also for health and safety reasons. Air leakage paths from a garage into the house can bring car exhaust, fumes from stored gasoline or other dangerous chemicals, or fire from the garage into the house. The floor over a garage is also a common area for freezing pipes and poor heat distribution. Provide both an interior and exterior air barrier to thoroughly isolate the floor system and reduce these potential problems.

FIGURE 4.2

Cape with conditioned basement and insulated rafters



This schematic shows the same Cape style house with a heated basement and kneewall areas. Note that the two choices are independent of each other, it is possible to have heated kneewall attics with an unheated basement, or the reverse.

Tuck-under garages and attached garages are especially important to seal and isolate from the rest of the house, not only because of heat loss but also for health and safety reasons. Air leakage paths from a garage into the house can bring car exhaust, fumes from stored gasoline or other dangerous chemicals, or fire from the garage into the house. The floor over a garage is also a common area for freezing pipes and poor heat distribution. Provide both an interior and exterior air barrier to thoroughly isolate the floor system and reduce these potential problems.

5

Foundation

Foundation Moisture

Aside from structural concerns, the most important consideration for foundation design is moisture. No client wants a wet basement. No client wants a damp basement. No client wants mold in their basement. If a dry basement is your objective, the first priority should be protecting it from bulk water by directing water down and away from the entire house at every possible point of entry (see Figure 5.1). Top-down foundation drainage should be complemented by the following (see Figure 5.2):

- A continuous capillary break that separates the basement slab and foundation walls from the ground.
- A continuous air and insulation barrier (to reduce the risk for condensation).

You can't go back to add these later (for a reasonable cost) so the time to do it is when you build the foundation. This applies to full foundations, to crawlspaces, and to slab-on-grade construction. Even with these precautions, the foundation walls may still be damp at times. You can't guarantee that mold won't grow. You can, however, minimize the potential for conditions that foster mold growth, and maximize the potential for walls to dry when they do get wet. To satisfy the requirement for a vapor retarder on the interior (warm in winter) side of insulated foundation walls, it is best to opt for products with perm ratings closer to 1 (e.g., polystyrene foam), and to avoid stronger vapor barriers (e.g., polyethylene sheeting or foil-faced products) which limit the potential for drying. The figures in this chapter show several possibilities for relatively forgiving, mold-resistant, insulated basement wall assemblies. If the proper drainage and capillary breaks are not present, and if care is not taken to avoid the pitfalls illustrated in Figure 5.3, it is better not to build a conditioned basement so that the foundation walls do not need insulating.

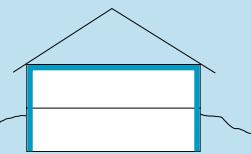
Energy Code Requirements

All basement spaces must be defined as “conditioned” or “unconditioned.” Conditioned space is defined as an area or room within a building that is either finished, or unfinished with an HVAC supply (or other intentional heat source). See Figures 4.1, 4.2 and page 45.

Conditioned Basements

In a conditioned basement, you must:

- Insulate the foundation walls on the inside or the outside of the wall. The required R-value depends on the results of your compliance analysis.
- Insulation must extend from the top of the wall to the basement floor (IECC 402.2.7).
- Insulate the band joist of the floor framing above the basement.
- Seal air leaks in the foundation walls and slab floor, as well as the sill / band joist area.
- If the foundation is insulated with rigid foam on the exterior, the insulation must be protected with a rigid, opaque and weather-resistant barrier that extends at least 6" below grade (IECC 303.2.1).

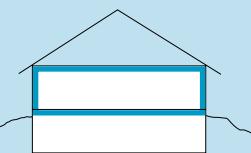


Important note: When you are doing compliance analysis on a conditioned basement, you must look at each basement wall separately and determine, wall by wall, whether the wall is 50% or more above grade or more than 50% below grade. Walls that are 50% or more above grade, must be added in with above grade walls in your calculations, and insulated to the same R-value. Walls that are 50% or more above grade are considered above grade walls and must be treated as such; walls that are more than 50% below grade are treated as “basement walls.”

Unconditioned Basements

In an unconditioned basement, you must:

- Seal air leaks in the floor system between the basement and the first floor, such as wiring and plumbing penetrations, and weatherstripping on the basement door. Include the basement door in your calculations.
- Insulate the floor above the basement or the basement walls. The required R-value depends on the results of your compliance analysis.
- Insulate the stairwell and the stairwell walls between the basement and conditioned first floor.



Slab-on-grade

Slab perimeter (edge) insulation must be installed where the slab is at or within 12" of grade (see Figure 5.7). This includes a slab-on-grade house or addition, the walkout portion of a heated basement, or a breezeway that shares a slab with the garage.

The R-value to use depends on the results of your compliance analysis. If the slab edge insulation is on the exterior, the insulation must be protected with a rigid, opaque and weather-resistant barrier that extends at least 6" below grade (IECC 102.2.1). An additional R-5 must be added to the required slab edge R-values for heated slabs.

Slab perimeter insulation must run all the way to the top of the slab. It may go down, or down and across, for a total of 24" in Climate Zone 5 and 48" in Climate Zone 6. See Figures 5.8-5.9 for examples.

Crawlspac

Historically, many building codes have required passive vents in exterior walls and minimal vapor barrier protection for crawlspaces floors. While this strategy may have helped to reduce moisture loads at times, it also introduced moisture in the summer when outdoor air is more humid than the cool crawlspace. Building science has shown that ventilating crawlspaces often does more harm than good, and codes are starting to catch up with the more sensible approach of building a tight crawlspace with good drainage and vapor control. In fact, national model energy codes are beginning to include exceptions that allow for unvented crawlspaces that are either vented to the interior, conditioned, or provide air to the return side of a heat and/or air conditioning system (IRC R408.3 and IECC 402.2.9).

Ideally, a crawlspace should be constructed like a short basement, including:

- Adequate footing drainage
- Thorough, durable and continuous vapor barrier
- A continuous air and insulation barrier

If the crawlspace has a dirt floor, it must be covered with a continuous Class I vapor barrier and all seams must overlap by 6 inches and be sealed with a good quality tape (e.g., 3M contractor's tape or Tyvek tape) or acoustical sealant. The vapor barrier must also be attached to the exterior walls, and all penetrations (including piers) must be sealed (IECC 402.2.8).

If a concrete slab is installed, rigid foam can be used in place of polyethylene.

The walls of an unventilated crawlspace must be insulated to a level that is determined by the results of your compliance analysis. When following the prescriptive path, crawlspace walls must be insulated to R-10/13. “10/13”

means R-10 continuous insulated sheathing on the interior or exterior of the wall or R-13 cavity insulation at the interior of the crawlspace wall. As with any basement, it's important to keep inside air away from the foundation wall to prevent condensation (Figure 5.11).

If the crawlspace is unconditioned, the thermal boundary may run across the floor of the house. As an alternative to insulating floors over unconditioned crawlspaces, crawlspace walls may be insulated when the crawlspace is unvented. Crawl space wall insulation must be permanently fastened to the wall and extend downward from the floor to the finished grade level and then vertically and/or horizontally for at least an additional 24 inches. Treat the floor over a vented crawlspace as you would a floor over an unconditioned basement: air seal and insulate to the level indicated by the compliance analysis. Also consider enclosing the insulation with rigid insulation that is fastened to the underside of the floor joists.

ENERGY STAR

To meet the ENERGY STAR performance guidelines, you need to insulate the basement walls (or the floor over the basement) to meet or exceed 2009 IECC levels and achieve Grade I installation per RESNET standards. Other recommendations:

- Install at least 4" of uniform sized, washed stone underneath the slab floor. This acts as a capillary break to help prevent absorption of ground moisture. It also makes it easy to add a sub-slab ventilation system for radon mitigation, if radon is found after construction (see pages 142-143).
- Insulate basement slabs, even in unheated basements. 1" of rigid polystyrene foam under the slab will keep it warmer in summer and reduce the chance of condensation which can wet the slab and lead to mold and mildew. This will also improve comfort and reduce moisture problems if the basement is finished off later.
- Do not install carpeting on below-grade slab floors unless the slab is insulated under its entire area, and the foundation is well drained. Moisture from condensation on an uninsulated slab, or drawn up by capillary action can lead to hidden mold and mildew problems in carpets.
- Always insulate under the entire surface of radiant heated slabs, even when the code does not require it. Most radiant equipment manufacturers specify insulation under the slab; if you are heating the slab, the insulation will reduce heat loss and improve comfort. Because of the high temperature of radiant heated slabs, a minimum of R-15 rigid insulation is suggested even though manufacturers may recommend less.

- Try to avoid crawlspaces. Where you do build over a crawlspace, be certain that the vapor retarder on the crawlspace floor is completely sealed at all seams and penetrations, and sealed to the wall.

Conditioned or Unconditioned?

The choice of whether to insulate the basement is yours, unless you have an intentional heat supply. There are several reasons for and against constructing a conditioned basement space:

- People often want to use basements. Even if they are not finished space, people often use basements for laundry, projects, storage or other uses. They really don't want the basement to be a very cold space in winter. If they do finish off the space later, it will be easier if the basement is already insulated.
- It's easier to air seal the foundation walls. Floors are usually far leakier than foundation walls, and are also harder to seal.
- There's no need to insulate HVAC ducts or pipes in a conditioned basement, which can save money.
- Warm basements are less likely to have condensation and related mold and mildew problems than cold basements.
- Insulating foundation walls has potential pitfalls. Exterior insulation may provide pathways for insects, must be protected, and tied in somehow with the wall above. Interior insulation cools foundation walls, and if drainage and insulation details are not built carefully there is substantial risk of condensation and mold growth.
- Insulating walls often costs more than insulating the floor over a basement.

Going Further

Other issues to think carefully about when planning foundation details include:

- **Concrete movement** and cracking can result in callbacks, air leaks and water entry in foundations. The EEBA Builder's Guide includes a discussion of concrete movement and control joints—which can reduce or eliminate these problems—as well as other foundation issues.
- **Moisture, drainage and capillary breaks**—Foundations are built in the ground. Depending on where you build, the ground is either sometimes wet or always wet. All foundations should be built with good drainage and moisture protection.
- **Insect entry**—Termites and carpenter ants can tunnel through rigid foam insulation. If the foam insulation is between the ground and

the wood frame of the house, they can use it as a way to get to the wood without being seen. For this reason some model codes have prohibited the use of foam insulation above grade in termite-prone areas. While New Hampshire is not generally considered to be termite-prone, termite protection still warrants consideration.

Termites don't eat foam board, but they will eat wood, causing structural damage. Carpenter ants don't eat either one, but they will nest in both and over long periods can cause structural damage.

There may be ways to effectively block insect entry from foam board to adjoining wood framing (or above grade foam sheathing); however, the details for such a system must be implemented very carefully. The energy code (and common sense) requires insulation in heated basements to the top of the foundation wall; after all, most heat loss occurs where the foundation wall is exposed above grade. You can't cut exterior foam board off at grade, so it may be better to insulate conditioned basements on the inside of foundation walls than to attempt an insect barrier between exterior foam and the wood framing.

- **Alternative foundation systems** such as insulated concrete forms (ICFs) or precast concrete walls can speed up the construction process (especially in the winter) and provide a pre-insulated, airtight assembly. They can be very cost-effective, when compared to a poured concrete wall with a built-up insulated stud wall.

FIGURE 5.1

Top-down foundation drainage

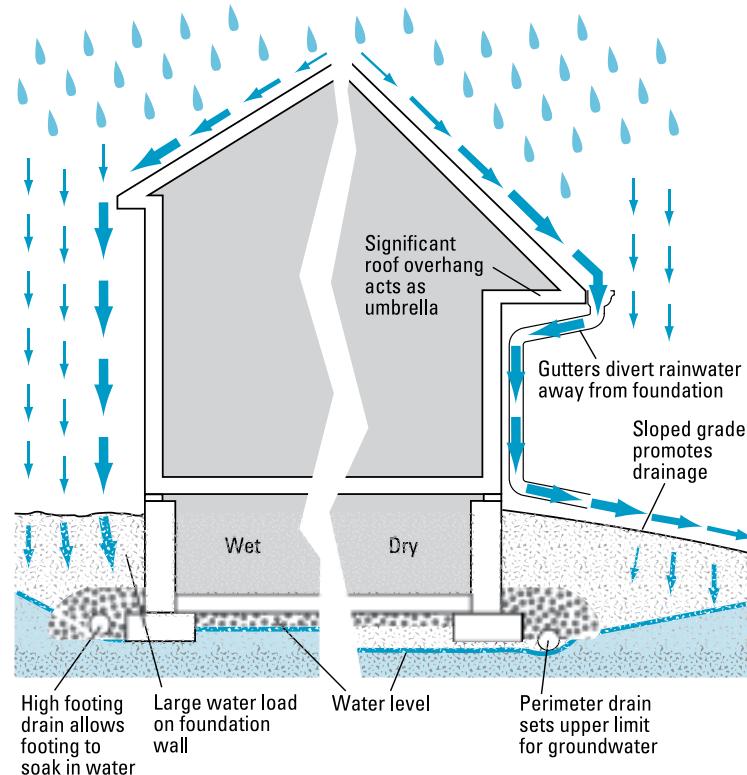
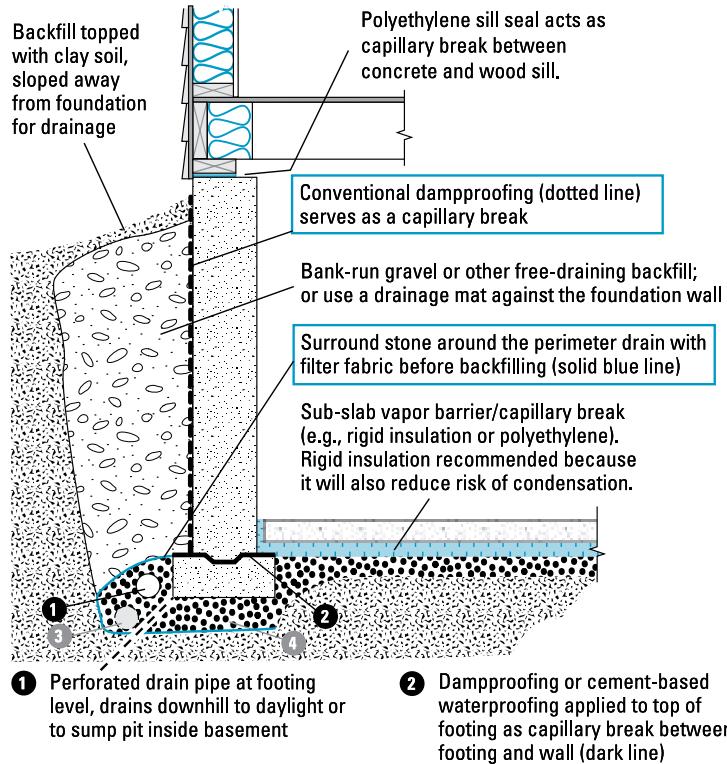


FIGURE 5.2

Foundation moisture control

All full and crawlspace foundations should incorporate these details.



Alternate Strategy—#3 and #4—more effective, where allowed by local codes.

Note: the footing drain can only be installed below the footing level if the footing is completely supported by uniform sized washed stone, which is noncompressible. When in doubt about the bearing capacity of the underlying soil, consult a soils engineer.

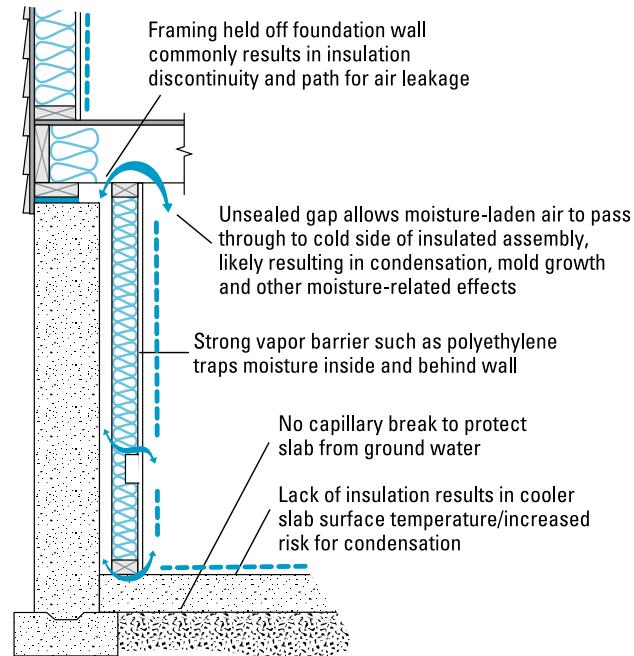
- 3 Drain pipe installed below footing level (and beyond load bearing range of stone, as indicated by dotted line) to carry water away from footing
- 4 4-6" washed, uniform sized stone (1/2" – 1 1/2") under footing provides capillary break and drainage.

▲ CAUTION: The stone surrounding the perimeter drain and under the slab and/or under footing must be uniform in size and washed (with no fine grains) to prevent settling or undermining.

TIP: One inch of rigid foam insulation under the slab will reduce the potential for condensation in the summer. Even if the foundation walls do not enclose conditioned space, condensation on the slab can contribute to moisture problems in the home.

FIGURE 5.3

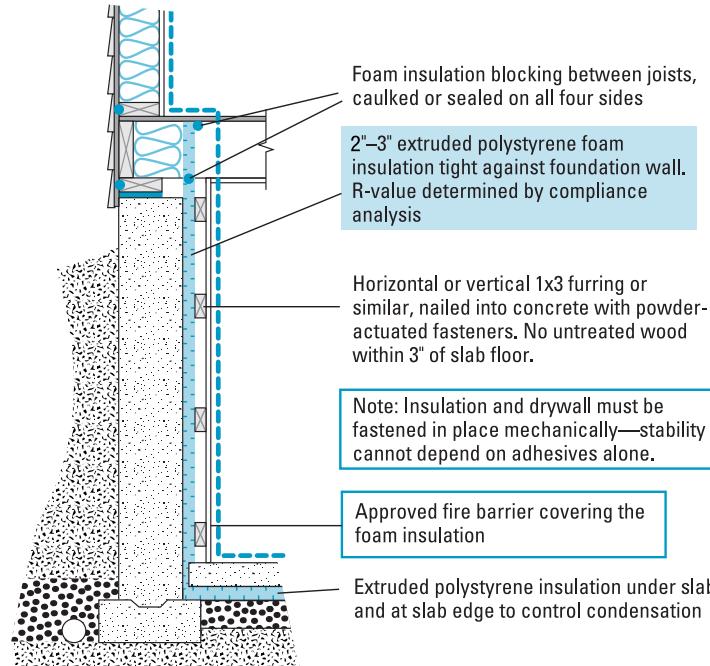
Foundation insulation pitfalls



▲ CAUTION: Even with careful detailing, a cavity-insulated frame wall is a poor choice for insulating foundation walls. All or most of the insulation should be continuous and sealed directly to the foundation (see Figures 5.4-5.6).

FIGURE 5.4

Conditioned basement with interior rigid foam



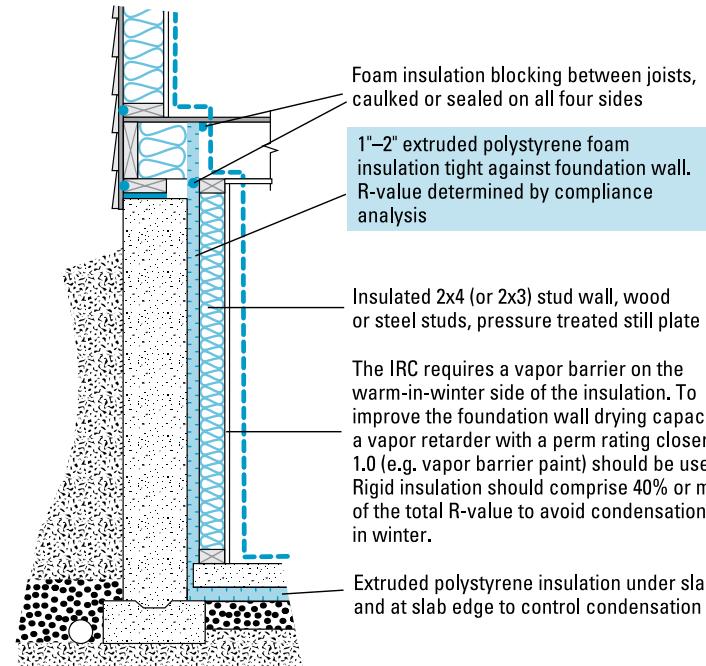
CAUTION: All vertical and horizontal joints in the insulation must be carefully sealed to prevent humid air from reaching the cool foundation wall, where it can condense.

TIP: Glass-faced gypsum board or cement “tile-backer” board is much less vulnerable to moisture than paper-faced drywall. It can be finished with veneer (skim-coat) plaster. Use vinyl or fiber-cement components for baseboard trim.

Foundation drainage and capillary break details not shown for clarity—refer to Figure 5.2.

FIGURE 5.5

Conditioned basement with interior stud wall

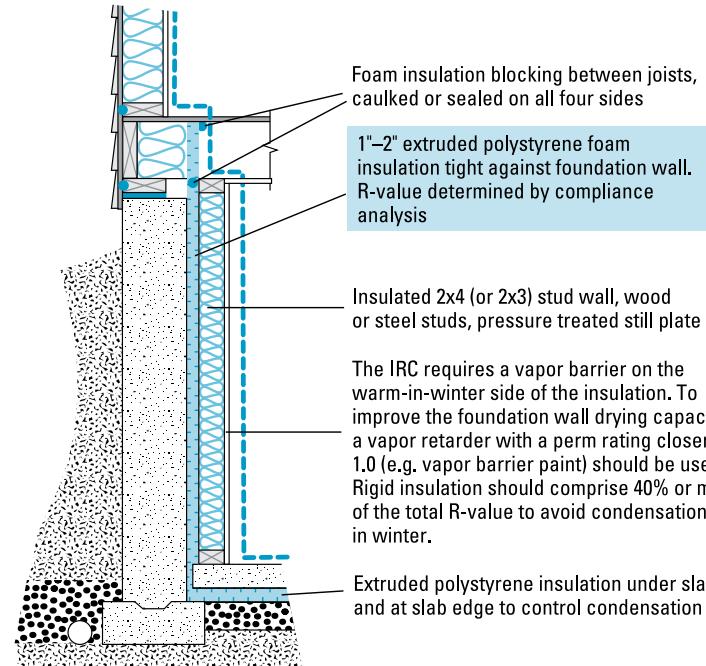


CAUTION: Exterior foam insulation may provide a pathway for termites and carpenter ants to reach framing. See page 45.

Foundation drainage and capillary break details not shown for clarity—refer to Figure 5.2.

FIGURE 5.5

Conditioned basement with interior stud wall



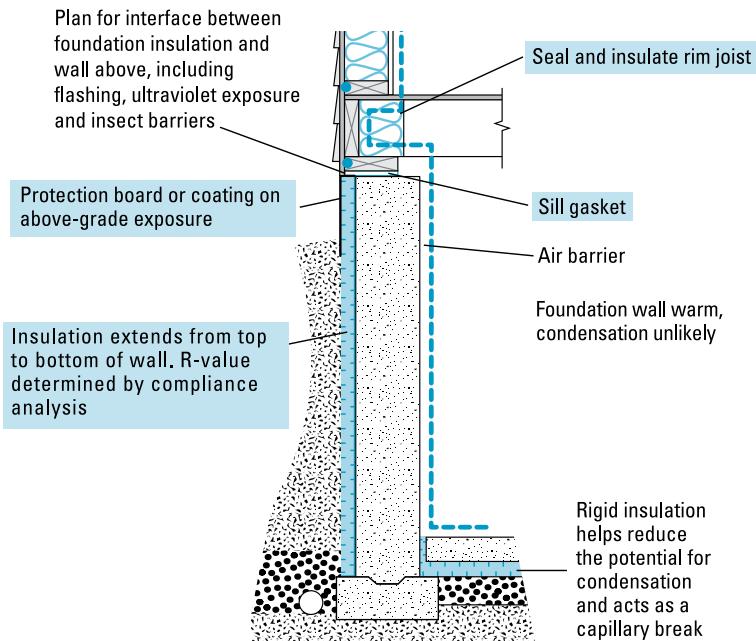
▲ CAUTION: All vertical and horizontal joints in the rigid insulation must be carefully sealed to prevent humid air from reaching the cool foundation wall, where it can condense.

TIP: Glass-faced gypsum board or cement “tile-backer” board is much less vulnerable to moisture than paper-faced drywall. It can be finished with veneer (skim-coat) plaster. Use vinyl or fiber-cement components for baseboard trim.

Foundation drainage and capillary break details not shown for clarity—refer to Figure 5.2.

FIGURE 5.6

Basement with exterior rigid foam

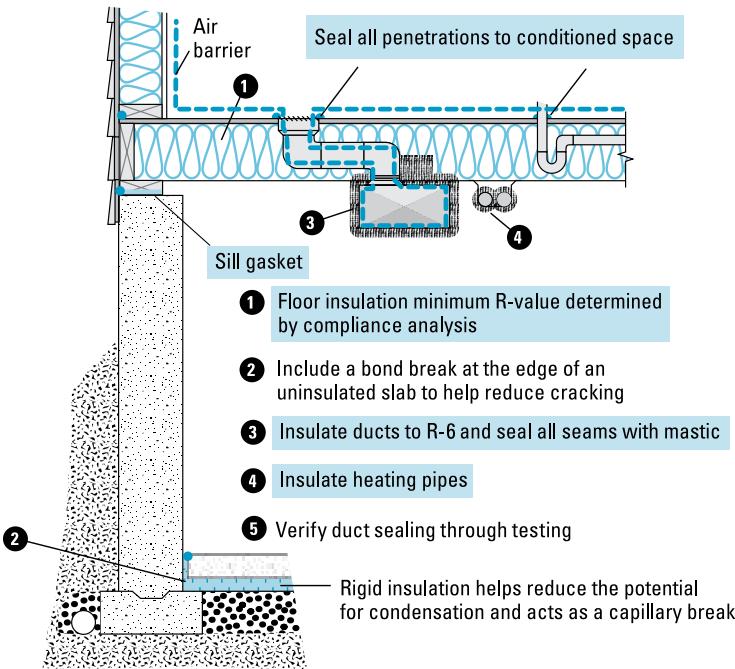


▲ CAUTION: Exterior foam insulation may provide a pathway for termites and carpenter ants to reach framing. See page 45.

Foundation drainage and capillary break details not shown for clarity—refer to Figure 5.2.

FIGURE 5.7

Unconditioned basement



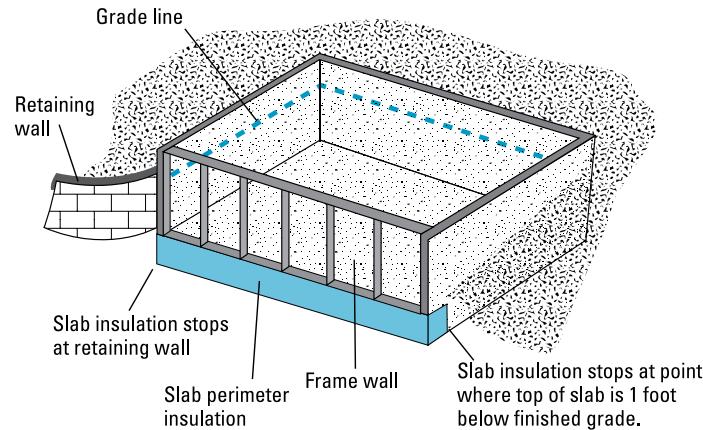
TIP: One inch of rigid foam insulation under the slab will reduce the potential for condensation in the summer. Even if the foundation walls do not enclose conditioned space, condensation on the slab can contribute to moisture problems in the home.

If conditioned space is adjacent to an unconditioned space (e.g., in a partially finished basement), then the wall between these two spaces must be insulated according to results of the compliance analysis.

Foundation drainage and capillary break details not shown for clarity—refer to Figure 5.2.

FIGURE 5.8

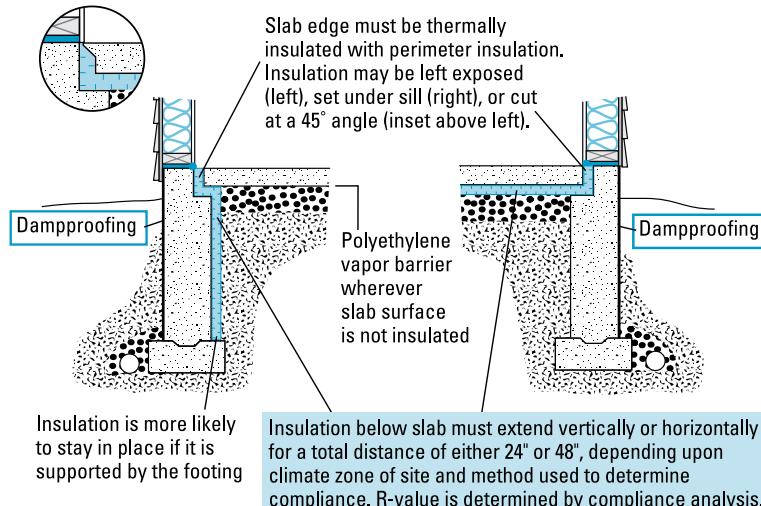
Slab edge insulation, walkout basement



This is a view of a basement with a frame wall on one side, showing the placement of slab perimeter insulation.

FIGURE 5.9

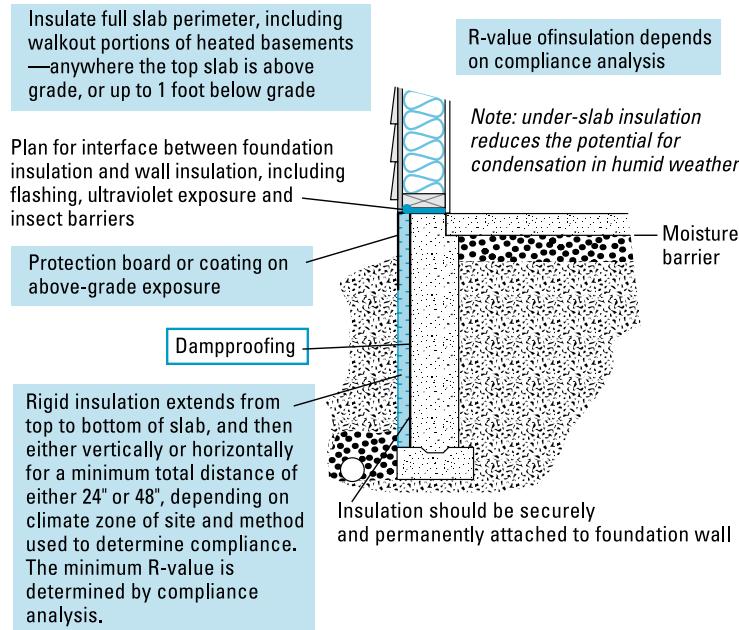
Slab on grade with interior insulation



Most of the foundation moisture control strategies shown in Figure 5.2 apply to slab on grade construction as well. Details not shown for clarity.

FIGURE 5.10

Slab on grade with exterior insulation

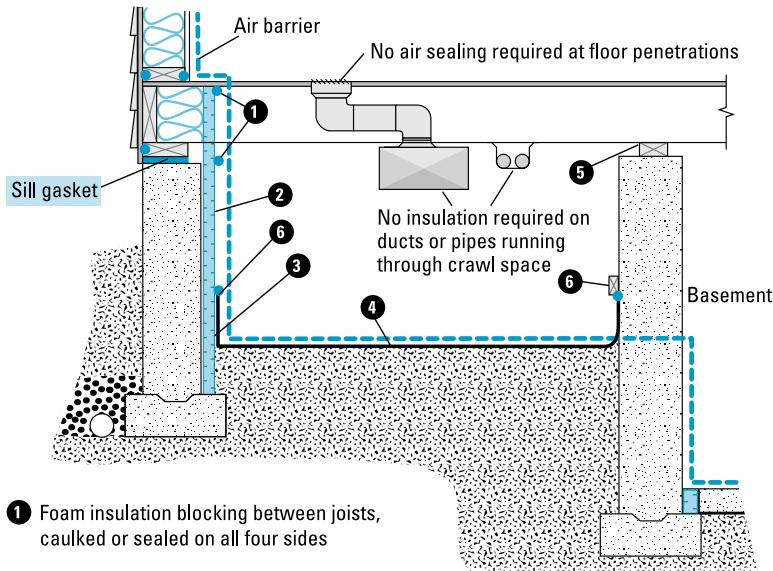


CAUTION: Exterior foam insulation may provide a pathway for termites and carpenter ants to reach framing. See page 45.

Most of the foundation moisture control strategies shown in Figure 5.2 apply to slab on grade construction as well. Details not shown for clarity.

FIGURE 5.11

Conditioned, unvented crawl space with interior insulation



① Foam insulation blocking between joists, caulked or sealed on all four sides

② Insulation must be in substantial contact with wall, with no gaps between pieces. It must extend to the top of the wall.

③ Rigid insulation must extend from top of slab down to the finished grade level and then vertically and/or horizontally for another 24", or 48" depending on the climate zone.

④ A minimum 4-mil thick polyethylene vapor retarder is required over exposed earth in unvented crawl-spaces. Vapor retarder must be lapped 6" and taped at all seams, and mechanically fastened and sealed to all walls, piers, columns and service penetrations.

⑤ No air sealing or insulation needed next to conditioned spaces.

⑥ Extend vapor retarder 12" up walls and columns, and attach with nailer and adhesive.

CAUTION: All vertical and horizontal joints in the insulation must be carefully sealed to prevent humid air from reaching the cool foundation wall, where it can condense.

Foundation drainage and capillary break details not shown for clarity—refer to Figure 5.2.

6

Framing

Energy Code Requirements

The following is a summary of the energy code requirements which might affect how a building is framed.

- **R-values of insulation**—The R-values determined from your compliance analysis can affect the dimensions of framing lumber you use. For example, an R-20 wall would often be built with 2x6 wall studs. However, there is almost always an alternative. For example, an R-20 wall can also be built with 2x4 studs, R-13 insulation and 1" of polystyrene foam board (R-5).
- **Air sealing details**—Most air sealing details can be carried out at any point up until the insulation and drywall are installed. However, many details are much easier to implement during framing. Some of these critical details include band joist/sill areas, housewrap details (if housewrap is used as an air barrier), dropped soffit areas, draftstop blocking between wall and roof or wall and floor assemblies, etc. Detail drawings showing appropriate air sealing of these areas are shown in Figures 6.1, 6.2, 6.8, and 6.11-6.18.
- **Raised truss construction** or equivalent roof framing (IECC 402.2.1). This type of construction gives you some credit in the code compliance analysis, and also performs better. Examples of raised truss equivalents are shown in Figures 12.4-12.7.

ENERGY STAR Homes

ENERGY STAR Homes Qualification: Framing

Component	Compliance	Guidelines
Thermal Enclosure Checklist	Address Thermal Enclosure Checklist items during framing stage (see Figures 6.8 and 6.11-6.18)	Same

The ENERGY STAR Version 3 Thermal Enclosure Checklist includes new requirements intended to reduce thermal bridging in the ceiling, walls and foundation. The most significant of these requirements involves reducing thermal bridging in the walls through one of the following methods (applicable to Climate Zones 5 and 6):

- Continuous rigid insulation or insulated siding $\geq R-5$
- Structural insulated panels (SIPs)
- Insulated concrete forms (ICFs)
- Double-wall framing
- Advanced framing, including all of the items below (see Figure 6.10):
 - All corners insulated $\geq R-6$ to edge
 - All headers above windows and doors insulated
 - Framing limited at all windows and doors
 - All interior / exterior wall intersections insulated to the same R-value as the rest of the exterior wall
 - Minimum stud spacing of 24" o.c. for 2 x 6 framing unless construction documents specify other spacing is structurally required

In addition to having to pay more attention to the air sealing details, you also may need slightly more insulation R-value in the walls or ceiling than you would just to meet the code. As noted previously, this can affect the dimensions of the lumber you use. However, there are some techniques you can use to help pay for these upgrades without compromising the structure of the building. Here are some suggestions:

- Use details that need less wood and leave more room for insulation at exterior wall corners, partition wall intersections, headers, and the like. See Figures 6.4-6.7. The EEBA *Builder's Guide* has a section on framing with detail drawings showing additional options.
- Housewraps have been marketed for years as air barriers, but their primary purpose and benefit is as a drainage layer behind the exterior cladding. No siding and flashing system is completely waterproof, so a dependable drainage plane under sidings is needed as a secondary line of defense. Appropriate counter-flashing details are critical, and a vented rain screen can provide the best performance for keeping water out of the building. Housewrap, properly installed and sealed with tape, can contribute slightly to the air tightness of a building, but does nothing to slow down air leakage in most large leaks, which are located in basements and attics.

In addition, plastic housewraps may be incompatible with unprimed cedar and redwood, and with cement stucco materials; and perforated plastic housewraps have been shown to leak water much more rapidly

than unperforated plastics or felt paper. Felt paper or building paper may be a good alternative as a drainage plane. The EEBA *Builder's Guide* has in-depth discussions about rain drainage planes and air flow retarder systems.

- Discuss HVAC layouts with mechanical subcontractors before framing. If you can adjust framing to allow space for ducts and pipes, lay outs can be more efficient and less costly, and less damage will be done to the frame during installation. For example, if a long center wall in a two-story house is framed with 2x6 studs, duct risers can be easily installed for floor registers in the upper story. Be sure to align floor framing with wall studs. At the very least, be sure that adequate mechanical chases exist. This type of approach can save on duct installation costs. The EEBA *Builder's Guide* section on design has more ideas related to HVAC integration.
- Consider sealing air leaks in the exterior of the walls as well as the interior. Two air barriers are better than one air barrier. Exterior air barriers help keep cold out and help prevent wind-washing of the cavity insulation, and they are easy to install (see the EEBA *Builder's Guide* section on air barriers).

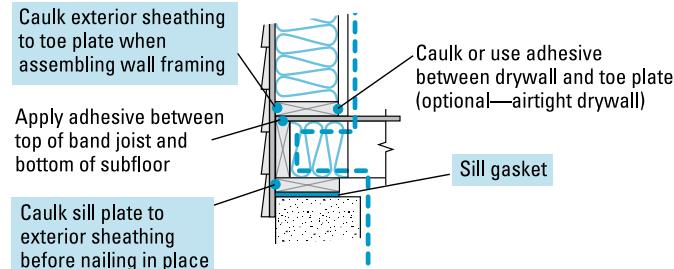
Going Further

Use advanced framing techniques that allow you to use less wood in the frame of the building, leaving more room for insulation and more room in the budget (see Figures 6.9-6.10). You can choose to use some of these techniques and not others; but you do have to think about how to apply these details. For example, don't use single top plates unless you "stack" roof, wall and floor framing. Don't use a single stud at the rough opening unless you hold the header up with hangers rated for the load. When they are applied properly, these techniques meet codes and work well. For more detail on advanced framing (sometimes called "Optimum Value Engineering") see *Cost Effective Home Building: A Design and Construction Handbook* by NAHB (contact information in Appendix B).

Think about the ways in which framing affects the installation of an effective rain control system (roofing, siding, trim, flashing, etc.), and an effective water vapor control system (vapor retarders, roof ventilation, etc.). For example, roof framing has a direct impact on the effectiveness of various roof ventilation strategies. See the EEBA *Builder's Guide* for more on rain control, framing details for moisture control, insulation, sheathings and vapor diffusion retarders.

FIGURE 6.1

Sealing band joists during framing



6

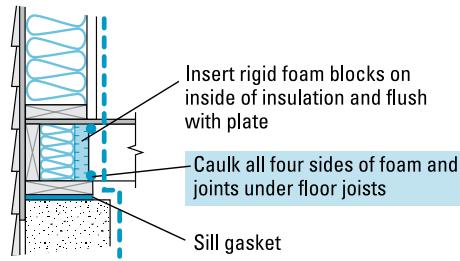
Framing

TIP: For better results, also use construction adhesive when setting the band joist on the sill.

Remember to caulk or tape vertical seams between sheathing panels.

FIGURE 6.2

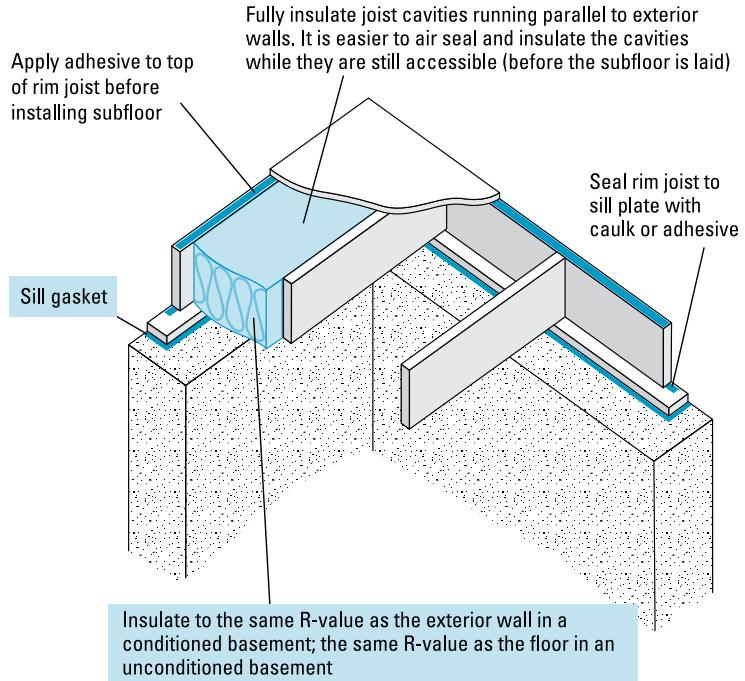
Sealing band joists after framing (alternate method)



Sealing the band joist is easiest to do during framing, but if it is missed at that time, this technique works well also.

FIGURE 6.3

Sealing and insulating band joists during framing



6

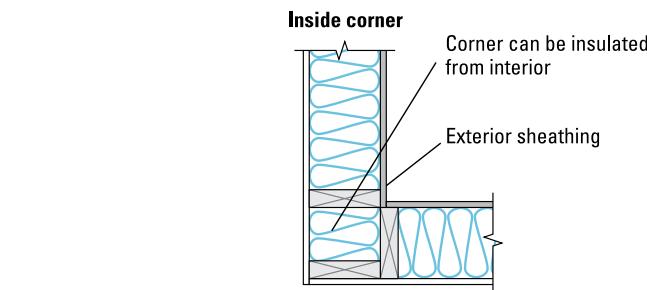
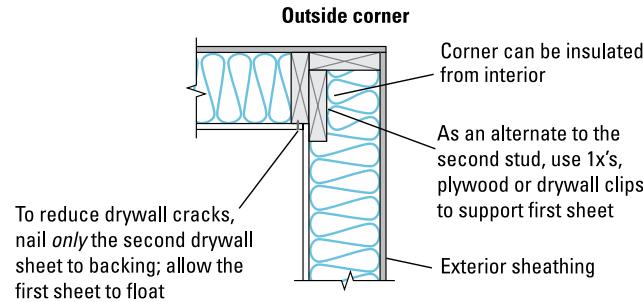
Framing

TIP: If you use a blown-in or sprayed insulation such as foam, blown-in cellulose or fiberglass, or a similar system, this area can usually be insulated with the rest of the house.

Insulating the band joist after the floor sheathing is installed can be very difficult, depending on the joist layout. Care must be taken to keep insulation dry when installed during framing.

FIGURE 6.4

Insulated three-stud corners



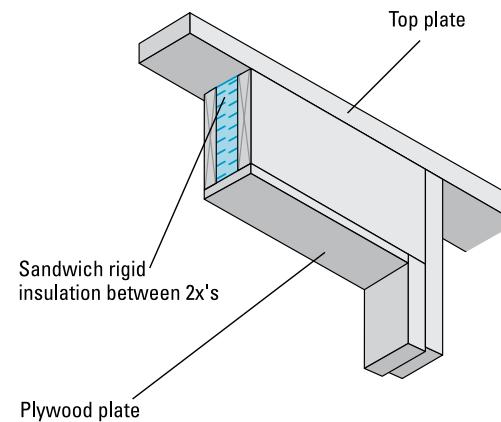
6

Framing

Conventionally framed corners are difficult to insulate and use more wood than insulated three-stud corners. For more savings and reduced drywall cracking, use clips for drywall backing at outside corners instead of the third stud.

FIGURE 6.5

Insulated header in a 2x6 wall



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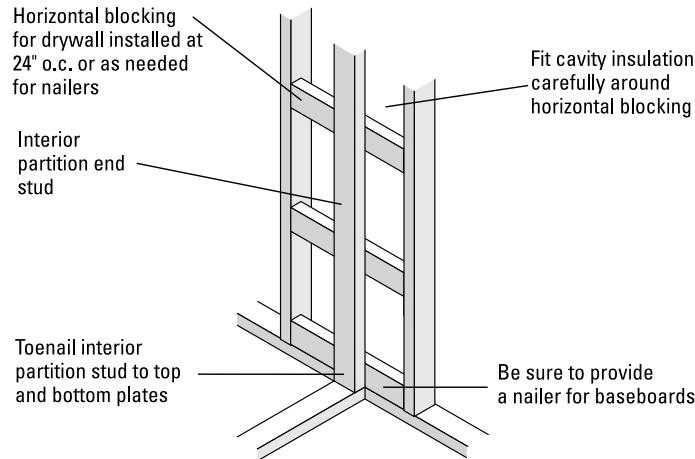
Framing

TIP: Use a few standard header sizes that will work in several locations. There is no need to size all headers equally.

As an alternative, insulated headers pre-manufactured from engineered wood I-beams and rigid foam may be used. Follow manufacturer's instructions regarding acceptable loading, span and support.

FIGURE 6.6

Ladder blocking for interior partition walls



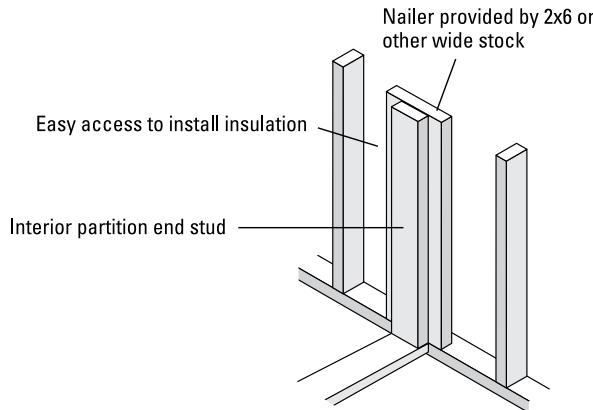
6

Framing

Conventional box channels for partition walls are difficult to insulate. Ladder blocking (or vertical backing, Figure 6.7) use less wood, are easier to insulate, and are easier for electricians as well. See Figure 11.3 for air sealing details.

FIGURE 6.7

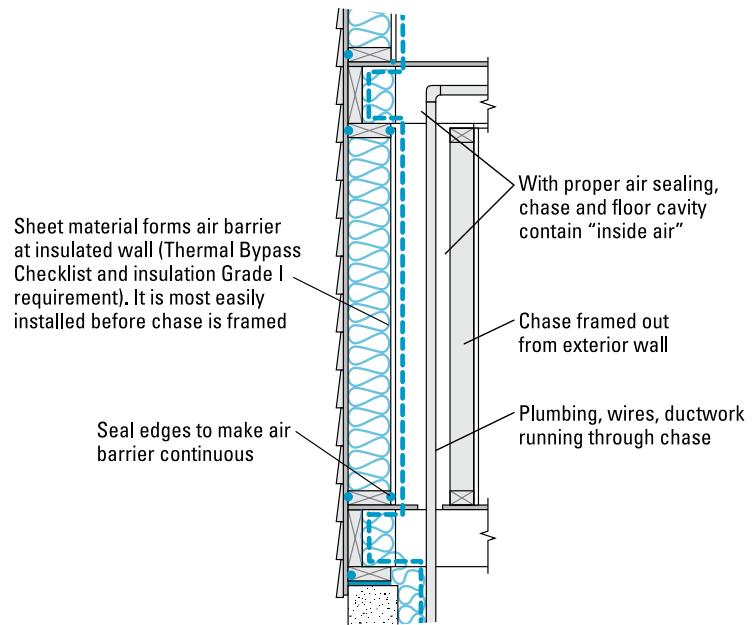
Drywall backing for interior partition walls



Vertical nailing stock can also be replaced by drywall clips to support drywall.

FIGURE 6.8

Cavity sealing example: chase on exterior wall



6

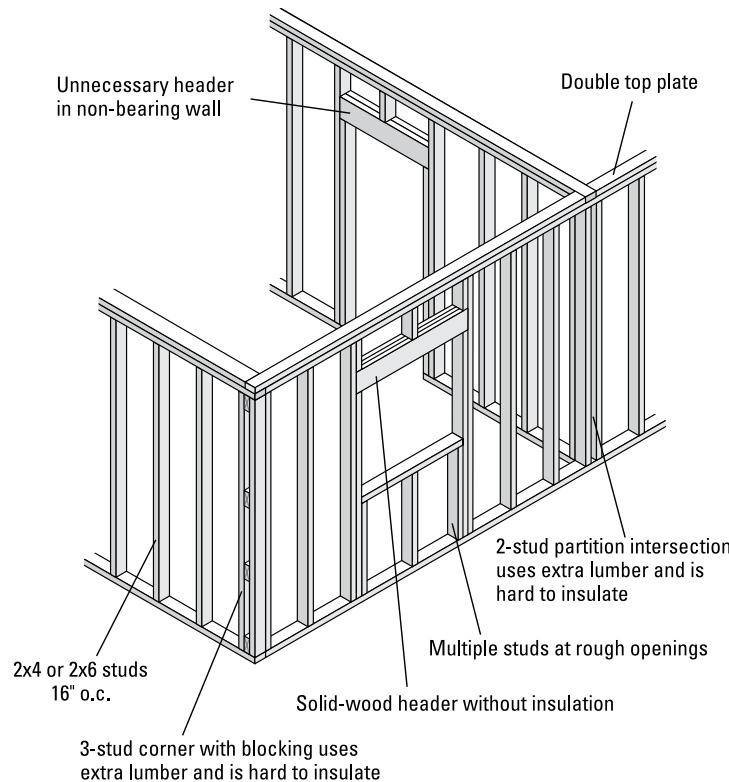
Framing

FIGURE 6.9

Conventional framing

6

Framing



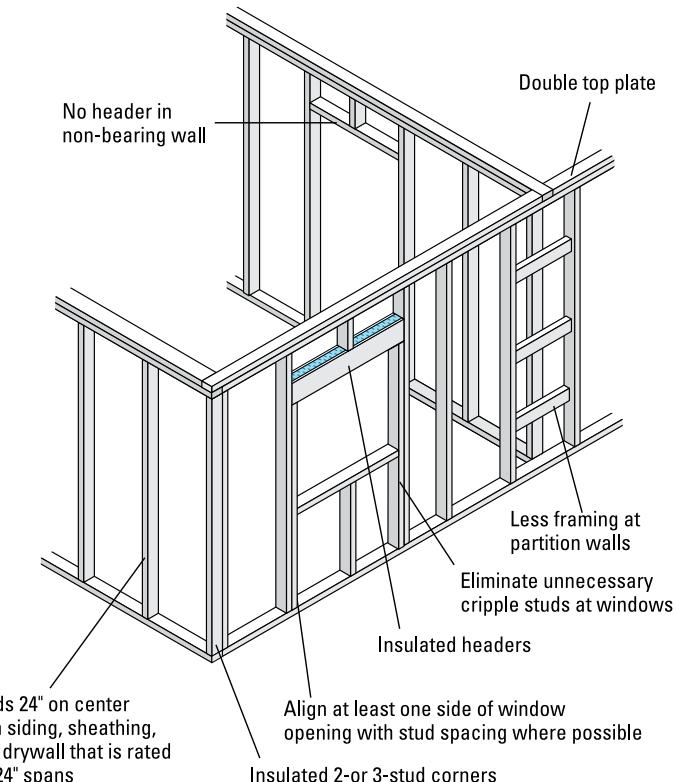
Standard framing techniques use unnecessary wood and leave less room for insulation. Advanced framing techniques are tested and proven by the National Association of Home Builders, and meet structural codes. For more detail on advanced framing (sometimes called “Optimum Value Engineering”) see *Cost Effective Home Building: A Design and Construction Handbook* by NAHB (contact information in Appendix B).

FIGURE 6.10

Advanced framing

6

Framing



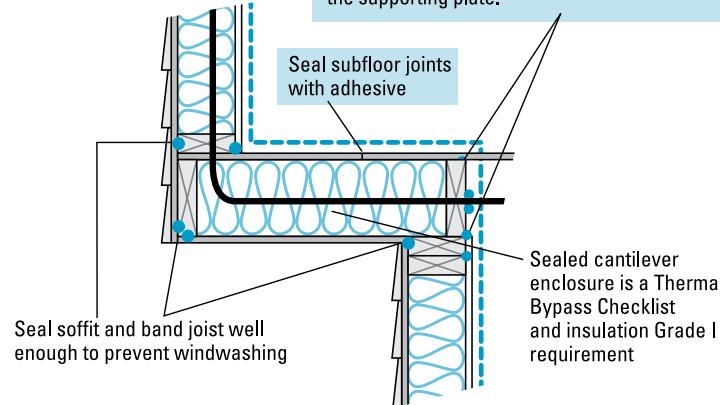
Advanced framing uses up to 25% less wood, increases overall insulation R-values by 5 to 10%, and costs less to build. The advanced framing techniques shown in this diagram are some of the simplest ones to incorporate into the structure of a building. Many other techniques are not shown. For more information about a wider variety of advanced framing opportunities, see the associated resources listed in “Framing/Alternatives” section of Appendix B.

FIGURE 6.11

Exterior cantilever floor with interior air sealing

Seal all penetrations through the blocking and the subfloor

Seal solid wood blocking or rigid insulation on all four sides (flexible foil-faced, bubble pack insulation is an acceptable blocking material where large penetrations have been made). The blocking should sit on the inner edge of the supporting plate.



6

Framing

CAUTION: Blocking is often pushed out by subcontractors. Encourage subs to make slightly oversized holes in blocking which are easier to seal later, rather than removing the entire piece.

FIGURE 6.12

Tuck-under garage

Seal all subfloor penetrations

Seal subfloor joints with adhesive

Seal solid wood blocking or rigid insulation on all four sides (flexible foil-faced, bubble pack insulation is an acceptable blocking material where large penetrations have been made). The blocking should sit on the inner edge of the supporting plate.

Seal garage ceiling framing and drywall to keep outside air from pipes and ducts

Seal all penetrations through blocking

Sealed garage ceiling enclosure is a Thermal Bypass Checklist requirement

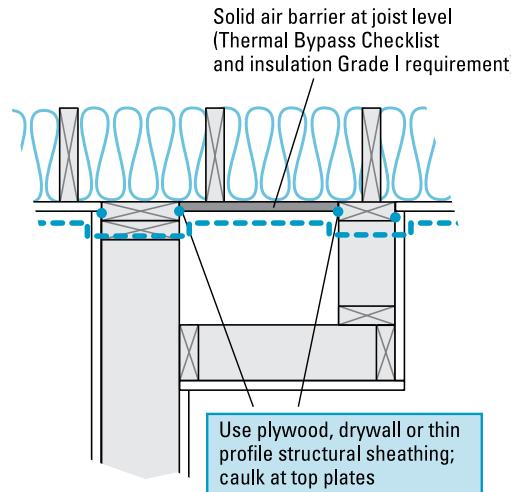
6

Framing

Tuck-under garages and attached garages are especially important to seal and isolate from the rest of the house, not only because of heat loss but also for health and safety reasons. Air leakage paths from a garage into the house can bring car exhaust, fumes from stored gasoline or other dangerous chemicals, or fire from the garage into the house. The floor over a garage is also a common area for freezing pipes and poor heat distribution. Provide both an interior and exterior air barrier to thoroughly isolate the floor system and reduce these potential problems.

FIGURE 6.13

Dropped soffit on interior wall

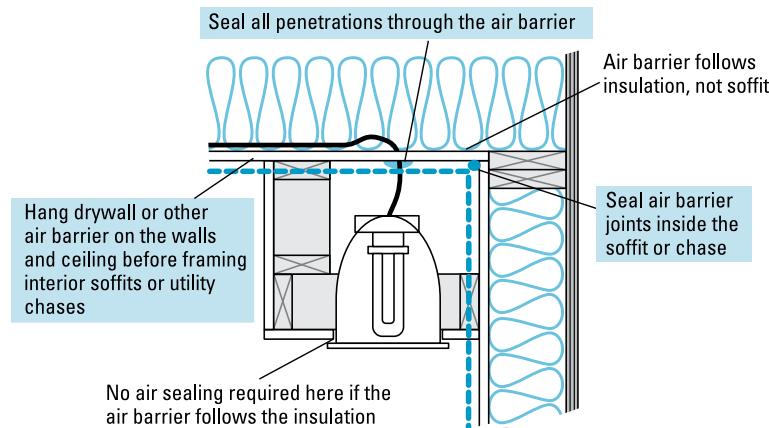


6

Framing

FIGURE 6.14

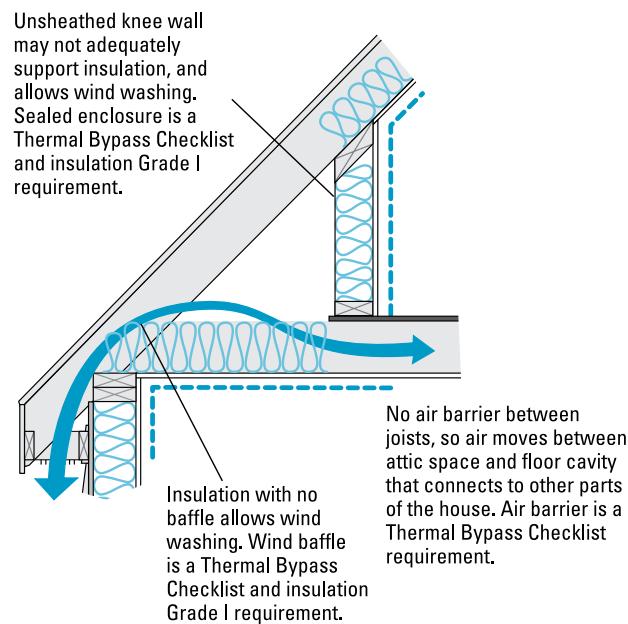
Interior soffit on exterior wall



Dropped soffits are commonly built with direct air paths from inside interior walls into attics. When recessed lights are installed, heat from the lights drives air leakage even faster. Installing air barriers before framing the soffit requires coordination of framing crews and materials.

FIGURE 6.15

Typical 1½-story knee wall



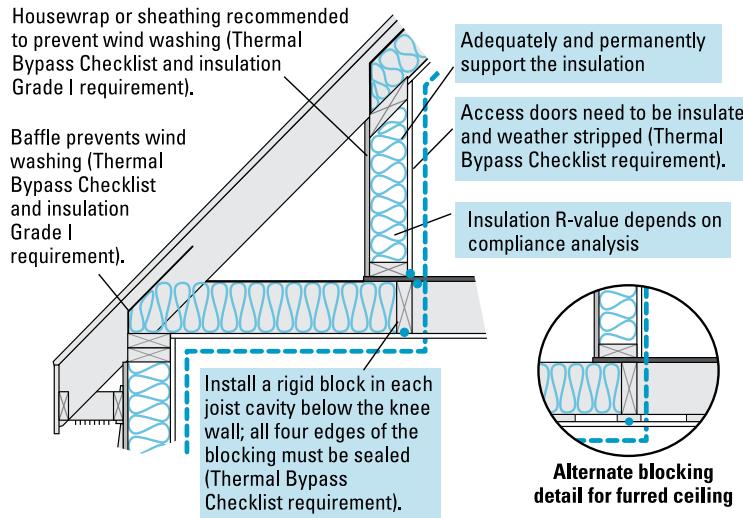
6

Framing

Typical knee wall details that are found in cape style homes, bonus rooms over garages, and the like are one of the largest and most common air leakage problems. This figure shows the air movement that allows outdoor air into all the joist bays, between floors. This problem can be eliminated by careful blocking of the floor framing under the knee wall, or by insulating the rafters and providing an air barrier, as shown in Figures 6.16-6.17.

FIGURE 6.16

1½-story knee wall outside the air barrier



6

Framing

FIGURE 6.17

1½-story knee wall inside the air barrier

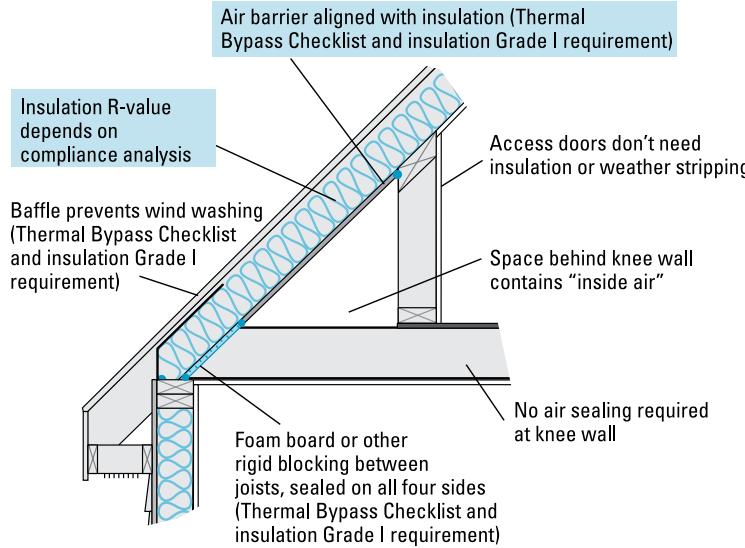
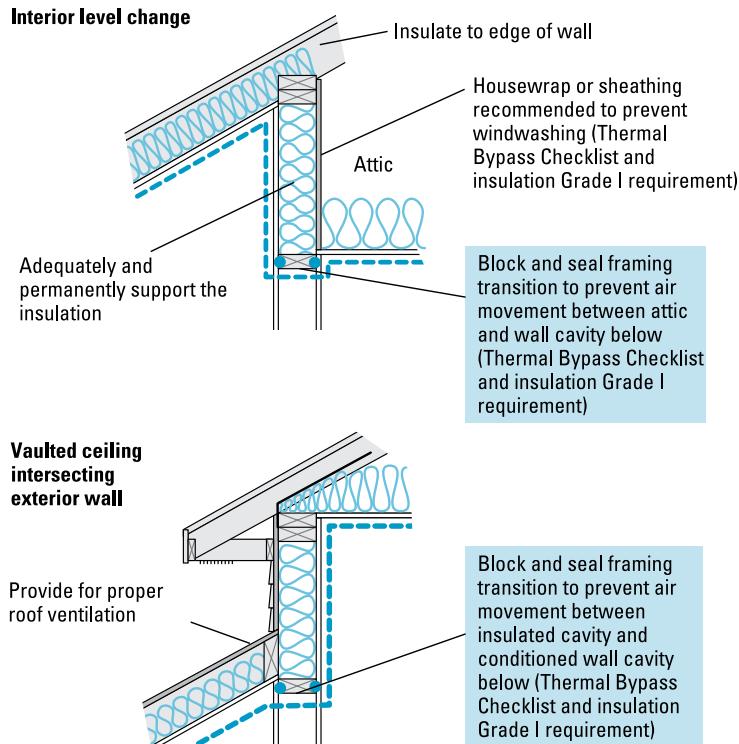


FIGURE 6.18

Sealing split levels



6

Framing

The lack of draftstop blocking in typical split-level details is another large leak. Be especially careful around stairways framed near these areas in "Trilevel" homes.

7

Windows and Doors

Energy Code Requirements

The primary window requirement in the energy code is for the *U-factor* of installed windows (which includes skylights and glass doors). Note that the U-factor is $1/R$, which means smaller U-factors have better thermal performance. This U-factor requirement will vary depending on the results of your compliance analysis. There are only two ways that the code lets you determine the U-factors for a given window:

- **NFRC rating (IECC 303.1.3)**—In order to take credit for a manufacturer's rated "U-factor," the product must be listed by the National Fenestration Rating Council (NFRC). The rating is based on simulations that are verified by a laboratory test, and its purpose is to provide a "level playing field" for all manufacturers to compare their products. The rating information should be available in product catalogs. Additionally, an NFRC sticker attached to every window unit displays the U-factor, along with other performance ratings that are less significant in the northern climate (see Figure 7.1). Be sure you don't remove the stickers until your building inspector has verified the installed product's U-factors!
- **Default tables**—For products that do not have an NFRC rating, you can use IECC Tables 303.1.3 (1 through 3). These tables contain default U-factors and Solar Heat Gain Coefficients (SHGC) for windows, glass doors, skylights and doors of various types. The main reason for these tables is to provide U-factors for the occasional non-rated side lite, transom window, decorative glazing unit, or door. You can use the default values for every window in a house, as long as the house passes the compliance analysis. However, the default U-factors are conservative, and don't allow credit for low-e coatings, gas fills, or any other feature that can't be verified in the field.
- **Remember** that when you calculate window (or skylight or door) area for the purposes of code compliance, you must use the whole unit area (frame dimensions or rough opening). Don't use glass or sash sizes.

Prescriptive Compliance

If you are demonstrating compliance prescriptively, you will have a “Maximum” U-factor to use for all windows in the house. If you have windows (or skylights) with different U-factors, you can do an average U-factor calculation for the whole group. A worksheet for that purpose is included in this guide (see Appendix A). 15 square feet of glazed fenestration and one opaque door (up to 24 square feet) per home are exempt from the U-factor and SHGC requirements.

Log Walls – All windows in log walls must have an area-weighted average U-factor of 0.31 or less

ENERGY STAR Homes

ENERGY STAR Homes Qualification: Windows and doors

Component	Compliance	Guidelines for Compliance*
Windows	All windows, doors and skylights must meet or exceed the U-factor and SHGC requirements specified in the 2009 IECC.	Window Max U factor: 0.35 Skylight Max U factor: 0.60 Max SHGC: No requirement
Doors	U-factor determined by HERS compliance analysis	Max U factor: 0.35 Max SHGC: No requirement

*One door and 15 square feet of glazed fenestration are exempt per household. An area-weighted average of fenestration products will satisfy the U factor requirements.

*Windows in log wall must have a minimum U factor of 0.31.

Windows

High performance window technology has developed rapidly in recent years thanks in large part to ENERGY STAR standards and energy codes. Double-paned, low-e windows have become the norm and triple-paned windows are becoming more affordable. High performance windows save energy, reduce condensation and improve comfort.

The four main components of high performance windows are low-emissivity (low-e) coated glass, gas fills, edge spacers and insulated frames. A low-e coating is a thin, invisible metallic film that is added to the inside surfaces of the glass. This coating has the effect of reducing the radiative coupling between panes of glass, markedly improving thermal performance. Most high performance windows use argon gas fills to “insulate” between panes of glass. Krypton has a higher performance than argon fills and is gaining traction in the market, but is more costly than argon filled windows. These gas fills are denser than the gas—air—that is used in standard double windows. The higher density of the gas reduces conductive looping inside the

window, improving the thermal performance even more. In between panes of glass are “warm-edge” spacers. These edge spacers are made of plastic or foam (instead of metal, which was used in the past). Consequently, less heat is conducted through the frames of the windows. Extra layers of glass (or more commonly, plastic films such as “heat mirror”) with additional low-e coatings are available as well—usually at a premium price, but they are increasingly affordable. The best (highest performance) windows currently available combine all of these features and have frames that are made of foam-filled rigid fiberglass. Foam-filled fiberglass frames conduct less heat than the typical wood or vinyl frames, and they are generally very durable and dimensionally stable.

To get a complete picture of the factors that affect the impact of window type on the energy performance of the building, you must also consider the following:

- **U-factors**—There are many different performance numbers associated with a given window type (see Figure 7.1). Use the whole-unit U-factor (as determined by the National Fenestration Rating Council [NFRC]) to compare products. The lower the U-factor, the better it performs.
- **Solar Heat Gain Coefficient (SHGC)**—The SHGC measures how well a window blocks heat from sunlight. The SHGC is the fraction of the heat from the sun that enters through a window, expressed as a number between 0 and 1. The lower a window’s SHGC, the less solar heat it transmits.
- **Orientation**—South facing glass reduces heating loads and adds little to cooling loads. South facing glass is good. If you have south facing glass area (not including frame area) that’s more than 7% of the floor area of the building, you should think about adding extra thermal mass to avoid overheating. East and west facing glass does not reduce heating loads in winter, but is the primary source of summer cooling loads. Limit east and west glass if you can; if you need large areas of glazing in these directions, consider using “southern” low-e products (which often cost the same if you order in advance) with low solar heat gain coefficients (SHGC).
- **Shading**—is another way to reduce unwanted heat gain from east and west facing glass. Trees, overhangs, decks, window covers, or awnings can all be used to reduce the time that the sun shines in these windows. On the south side, properly designed shading can admit the sun in winter when it is low in the sky and block it out in summer when the sun is high.

Window installation is another factor that can affect not only the energy efficiency of a house, but also its durability. Regardless of the window type selected, care should always be taken to ensure that any water that gets behind the siding or through the window frame is drained and shed down,

out and over the sheathing wrap or building paper. Use a properly lapped sill flashing that is integrated with the building drainage plane. Compliance with the ENERGY STAR Homes Version 3 Water Management System Checklist requires that window and door openings are properly flashed, including pan flashing at sills, side flashing that extends over pan flashing, and top flashing that extends over side flashing. An excellent resource for this and related flashing details is the EEBA Water Management Guide (see Appendix B). Outdoor air should also be prevented from entering the house by sealing the window frame and/or casing to the rough opening in the framing (see Figures 7.3 and 7.4).

By carefully selecting windows, you can trade off upgrade costs immediately with dollars saved elsewhere. High performance glazings, when coupled with air sealing, can reduce peak heating and cooling loads, and allow substantial savings on mechanical equipment costs. For example, upgrading from double-pane to low-e glazings (or from low-e to heat mirror films), can reduce cooling loads by 1/2 to 1 ton in a typical house, saving enough on HVAC costs to pay for the window upgrade. Also, higher average surface temperatures and lack of drafts may allow HVAC contractors to put supply registers or baseboards near inside walls, saving significant installation costs.

Doors

Doors can generally be divided into two categories—those that are insulated and those that are not. Insulated doors typically have R-values between 2.5 and 7. Metal doors perform much better if they have thermal breaks—interruptions in the conductive metal components—built into the door and frame. Insulated fiberglass doors can achieve high R-values without special thermal breaks. Uninsulated doors (e.g. all wood doors) have R-values closer to 1. Most new doors that have any amount of glazing are also NFRC-rated (by U-factor), which makes it easier to compare one door to the next. Usually, aesthetics and price drive consumers to select one door over another, which is fine; doors take up a small enough area of the thermal boundary that the R-value has a small impact on the overall performance. Of course, all other things being equal, it's still a good idea to choose the most efficient one available.

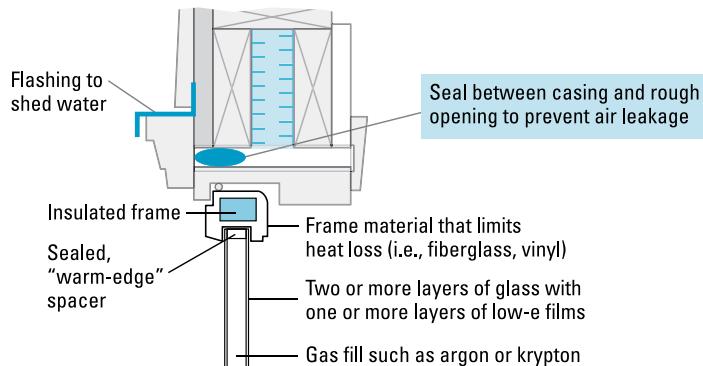
FIGURE 7.1
NFRC Sticker



TIP: The National Fenestration Rating Council (NFRC) rating is the only way allowed by code to verify the manufacturer's rated thermal performance of windows, skylights and glass doors. A sticker similar to the one shown above is attached to each window. In addition to the performance ratings expressed above, condensation resistance (measured on a scale from 0 to 100; the higher the number the better) may also appear on the label. The ratings associated with condensation resistance and air leakage (measured in CFM/square foot) are optional; the manufacturer decides whether or not to include them. Performance ratings can also be found in the NFRC Certified Products Directory (see Appendix B), or can be obtained directly from the manufacturer.

FIGURE 7.2

Features of a high performance window



7

Windows
and Doors

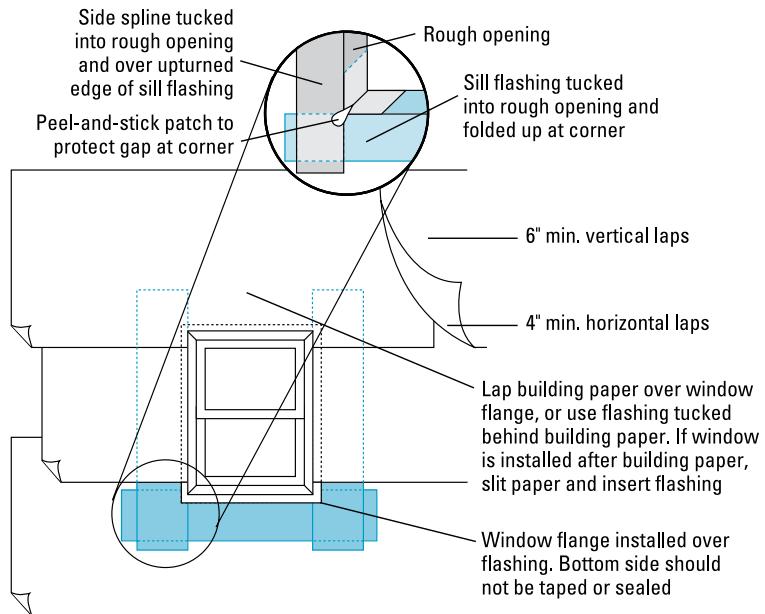
TIP: Most high performance windows are ENERGY STAR qualified. The parameters for ENERGY STAR qualified windows vary by climate. For New Hampshire, ENERGY STAR windows (and doors) must have a whole-unit U-factor of 0.30 or less. ENERGY STAR doors must have a U-factor of 0.21 if opaque.

NOTE: Window flashing should be integrated with building drainage plane; details not shown for clarity—refer to Figure 7.3.

FIGURE 7.3

Traditional style window flashing

Flashing, prior to window installation, 3D view



7

Windows
and Doors

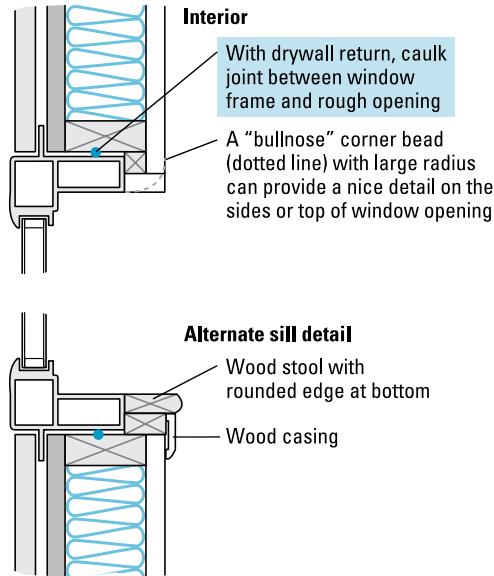
Note: Traditionally, the rough sill was prepared with felt or building paper; best practice today is to flash the rough sill with a more robust peel-and-stick membrane. A beveled or sloped sill or back dam to divert water to the exterior is also recommended.

▲ CAUTION: It is difficult to convey the steps required to effectively flash a window opening in a single drawing. Furthermore, there are many combinations of window type and wall assemblies, so one procedure cannot be portrayed to work in every situation. Construction scheduling also affects the detailing: the process is different if you install the windows before, or after, the sheathing wrap.

There are many ways to do this right, but there are even more ways to do it wrong. This figure is only meant to convey an overall strategy. For step-by-step guidance and better specifics, please refer to the EEBA Water Management Guide (see Appendix B for ordering information).

FIGURE 7.4

Window with drywall return



CAUTION: Do not use high-expansion foam. It may cause bowing of window and door frames and void the warranty.

NOTE: Window flashing should be integrated with building drainage plane; details not shown for clarity—refer to Figure 7.3.

8

Mechanical Systems

Energy Code Requirements

The energy requirements of the building code that apply to HVAC installations (IECC Section 403) are in addition to any plumbing, mechanical, and fuel gas codes that apply to these systems. Although it is generally the HVAC installer's responsibility to follow these requirements, the builder may also have to know what they are and to communicate them to the subcontractor for a given project because they are in the building code. A summary of the HVAC requirements is provided below. Remember that these requirements generally apply to all residential buildings, but more complex mechanical systems typically found in multifamily residences may have to meet additional requirements.

- **Heat loss calculations and system sizing (IECC 403.6 and IRC M1401.3)**—Heating and cooling systems must be sized in accordance with Air Conditioning Contractors of America (ACCA) Manual S, using load calculations that are based on ACCA Manual J (see Appendix B for ordering information) or another approved calculation method. The design parameters used for these calculations are given in IECC Chapter 3.

- **HVAC system efficiencies**—The minimum efficiency requirements for HVAC systems follow federal minimum efficiency standards. See the following table, the next bullets, and the NH specific amendments for more information on log homes.

Equipment	Rating	Minimum
Boilers (oil and gas)	Annual Fuel Utilization Efficiency (AFUE)	80*
Furnaces (oil and gas)	Annual Fuel Utilization Efficiency (AFUE)	78*
Heat Pumps (air source)	Heating Seasonal Performance Factor (HSPF)	7.7
Central Air Conditioning	Seasonal Energy Efficiency Ratio (SEER)	13

*Log homes must have a minimum efficiency 90 AFUE for gas heating systems and 84 AFUE for oil systems.

- **HVAC controls**—The following is a summary of the mandatory control requirements that are included in IECC section 403:
 - Every heating and cooling system must be equipped with at least one thermostat (IECC 403.1).
 - Where the primary heating system is a forced-air furnace, at least one programmable thermostat is required (IECC 403.1.1).
 - Heat pumps that include auxiliary electric resistance heaters must have controls that lock out the auxiliary heaters above a preset outdoor temperature (IECC 403.1.2).
 - Circulation pumps that are part of a circulating hot water system must be equipped with automatic or readily accessible manual shutoffs. (IECC 403.4).
 - All mechanical ventilation systems must have automatic or gravity-driven dampers at the points of intake and exhaust that close when the system is not operating. (IECC 403.5).
- **Duct and pipe insulation** (IECC 403.2 through 403.4) is required for all HVAC ductwork and pipes in unconditioned spaces. Supply ducts in attics must be insulated to a minimum of R-8. All other ductwork must be insulated to a minimum of R-6. All hydronic pipes that are either part of a circulating hot water system or carry water that is either less than 55°F or greater than 105°F must be insulated to a minimum of R-4 (per NH specific amendment).

The 2012 IECC requires all mechanical system and circulating hot water system piping to be protected from potential damage that can cause degradation of the material (sunlight, moisture, etc.).

• **Duct sealing** is required on all ductwork (IECC 403.2.2 and IRC M1601.3.1). All portions of stud bays or joist cavities used as ductwork must also be sealed. Building framing cavities may not be used as supply ducts. All connections and seams must be sealed with either mastic or fibrous tape embedded in mastic (see Figure 8.1). Only two types of tapes are permitted for use in duct sealing, and their applications are specific to the type of duct being installed. Respectively, tapes meeting UL 181A and 181B may only be used for rigid fiber ducts (A) and for flex ducts (B). Duct tape is not allowed for duct sealing.

• **Duct Testing** must be conducted to verify tightness unless they are located within conditioned space (IECC 403.2.2). Duct leakage limits are as follows:

- 8 cfm per 100 square feet of conditioned floor area of the house when measured at completion of construction. 4 cfm per 100 square feet is required under 2012 IECC.
- 6 cfm per 100 square feet of conditioned floor area of the house when

measured during rough in of the duct system, and when system includes the air handler. 4 cfm per 100 square feet is required under 2012 IECC.

- 4 cfm per 100 square feet of conditioned floor area of the house when measured during rough in of the duct system, and excluding the air handler (i.e. testing the ducts alone). 3 cfm per 100 square feet is required under 2012 IECC.

• **Pools**—All heated pools must be equipped with a pool cover and an on/off pool heater switch mounted for easy access. All pool pumps must be equipped with a time clock that can automatically turn off heaters and pumps according to a preset schedule.

• **Snow Melt System Controls** Snow and ice-melting systems must include automatic controls capable of shutting off the system when the pavement temperature is above 50°F and no precipitation is falling; and an automatic or manual control that will allow shutoff when the outdoor temperature is above 40°F.

• **Written materials** describing regular maintenance actions must be left with all HVAC and water heating equipment (IECC 303.3). A label with a reference to such material is also acceptable.

ENERGY STAR Homes

ENERGY STAR Homes Qualification: Mechanical systems

Component	Compliance	Guidelines
Heating	Minimum efficiency determined by HERS compliance analysis ENERGY STAR qualified heating equipment must be used	ENERGY STAR qualified furnace (min. 85 AFUE oil furnace; 90 AFUE gas furnace) or 85 AFUE boiler
Cooling (where provided)	Minimum efficiency determined by HERS compliance analysis Cooling system must be right-sized. ENERGY STAR qualified heating equipment must be used	Right-sized, 13 SEER minimum
Programmable Thermostat(s)	Determined by HERS compliance analysis	Required unless controls a zone with electric radiant heat
Ductwork, maximum allowable leakage (tested)	Leakage to outdoors \leq 4 CFM/100 square feet of conditioned floor area to outdoors or; Total duct leakage \leq 6 CFM/100 square feet of conditioned floor area	Leakage to outdoors \leq 4 CFM/100 square feet of conditioned floor area to outdoors or; Total duct leakage \leq 6 CFM/100 square feet of conditioned floor area
Duct insulation, minimum R-value	Determined by HERS compliance analysis	Supply ducts in attics R-8; All other ducts \geq R-6

HVAC Quality Installation Checklist

In addition to the general program requirements listed above, the HVAC Quality Installation Checklists must be completed by both the contractor and the rater. These checklists, along with a Guidebook may be obtained on the ENERGY STAR website (www.energystar.gov).

General Recommendations

- **Bring ducts and pipes inside**—Ducts and pipes in unconditioned attics, garages, basements and crawlspaces lead to higher heat loss, discomfort, and ice dams. Whenever possible, bring the mechanicals inside the thermal boundary of the house. Builders and designers can help make sure that framers leave room to run the heating and cooling distribution system inside the thermal boundary.
- **Avoid ducts in outside walls**—If you must put a heating duct in an outside wall cavity, install at least R-13 (2" polyisocyanurate will achieve R-13) rigid insulation between the duct and the exterior.

- **Use high efficiency equipment**—Many utility companies have rebates or incentives available to help offset the higher purchase price of high efficiency heating or cooling systems. These incentives are usually linked to the following ENERGY STAR performance standards:

Equipment	Rating	Minimum
Boilers (oil and gas)	Annual Fuel Utilization Efficiency (AFUE)	85
Furnaces (oil and gas)	Annual Fuel Utilization Efficiency (AFUE)	90
Air Source Heat Pumps	Heating Seasonal Performance Factor (HSPF)	9.25 - CZ 5; 9.5 - CZ 6
Ground Source Heat Pumps	Coefficient of Performance	3.3 - Water to air; 3.0 - Water to water
Central Air Conditioning	Seasonal Energy Efficiency Ratio (SEER)	14.5

Note that these performance standards are for HVAC systems only, and that the specification of these systems is only a requirement for the prescriptive compliance option.

- **Use sealed combustion equipment** to avoid backdrafting and carbon monoxide in the home. Figure 8.2 shows one typical backdrafting scenario; any large exhaust fan can backdraft atmospheric vented combustion appliances. By installing sealed combustion boilers, furnaces, and/or water heaters you can avoid the expense of building a chimney; many of them can vent through the side wall (see Figure 8.3).
- **Use integrated systems**—Integrated heating/hot water systems can save energy and also save on installation costs. An integrated system (a boiler and an indirect fired water storage tank) is much more efficient than a stand-alone tank, uses only one burner to do both jobs, and needs only one venting system. If forced air is desired, a boiler can provide heat through a “hydro-air” fan coil. In a house with small heating loads, the fan coil can be supplied by a small, high efficiency, stainless steel water heater with a heat exchanger. This approach also saves space. Avoid using a “tankless coil” in the boiler (not the same as an instantaneous “tankless” water heater) for water heating; they have the lowest efficiency of all and are not permitted when using the prescriptive ENERGY STAR compliance option.
- **Sizing** for air conditioning systems (prescriptive ENERGY STAR compliance requirement) is especially important because the ability to dehumidify is an important part of their job. When an air conditioner is oversized, it is not as effective at removing water from the air. The air gets chilled enough, but ends up “cold and clammy.” A properly sized air conditioning system not only saves money on installation, but actually provides a higher comfort level.

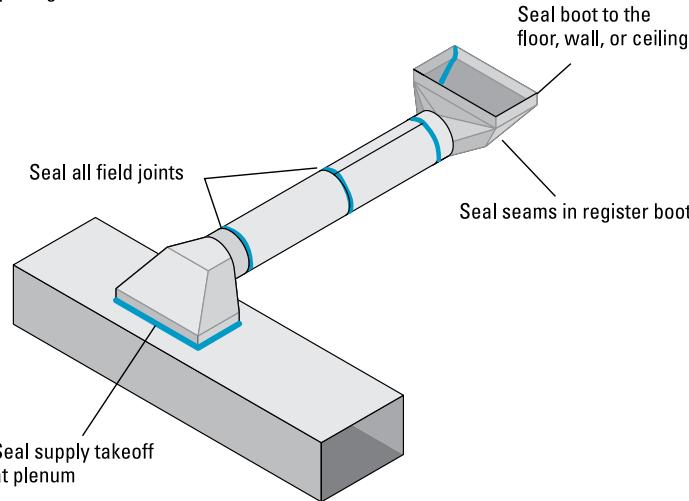
Going Further

There are a number of references listed in Appendix B specifically related to indoor air quality, ventilation, and HVAC systems.

FIGURE 8.1

Sealing duct runs within unconditioned spaces

Use mastic to seal all the locations shown here. Use fiberglass mesh as reinforcement for gaps larger than 1/8".



8

Mechanical Systems

Leaky ductwork in unconditioned basements and attics is a major source of heating and cooling losses. Run ducts inside the thermal boundary wherever possible; duct sealing is not required in conditioned spaces.

To apply mastic, use vinyl gloves and smear it in place by hand. Pay close attention to:

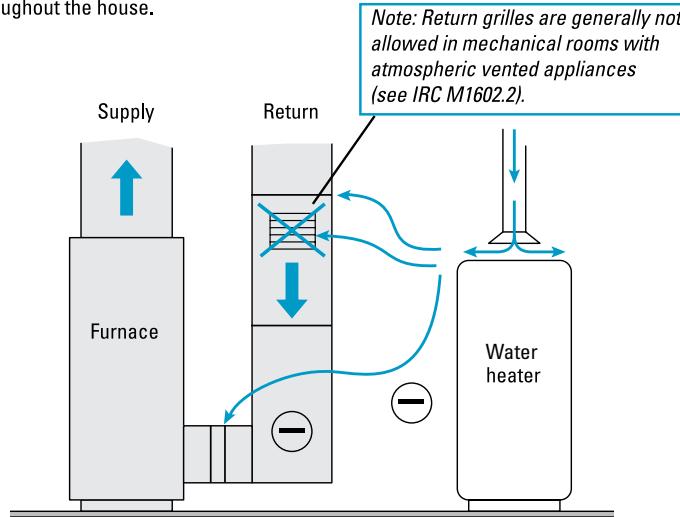
- folded corners on end caps, boots and takeoffs;
- plenum connections;
- filter racks;
- swivel elbows; and
- finger-jointed collars

TIPS: Mastic is much faster to install and more reliable than the more common aluminum tapes.

FIGURE 8.2

Depressurization and backdrafting

This figure shows a typical scenario. Leaks in return ducts depressurize the basement. Depressurization can backdraft the water heater vent or the furnace burner. Backdrafted combustion products, which may include deadly carbon monoxide, are then circulated throughout the house.



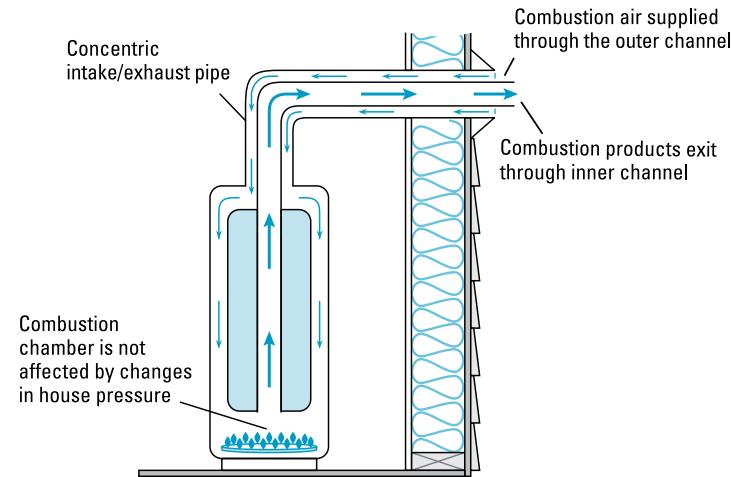
8

Mechanical Systems

Depressurization that causes backdrafting can be created by any exhaust appliance. The large ones that are most likely to create depressurization include range vents, whole house fans, dryers, central vacuum, and fireplaces without outdoor air supply. Leaks in return ducts and/or the presence of return air registers in the vicinity of a combustion appliance can also cause backdrafting (as shown in the diagram above). **Mechanical code requirements for passive combustion air inlets or volume of air space do not guarantee against backdrafting**, yet they add to building heat loss.

FIGURE 8.3

Direct vent water heater



8

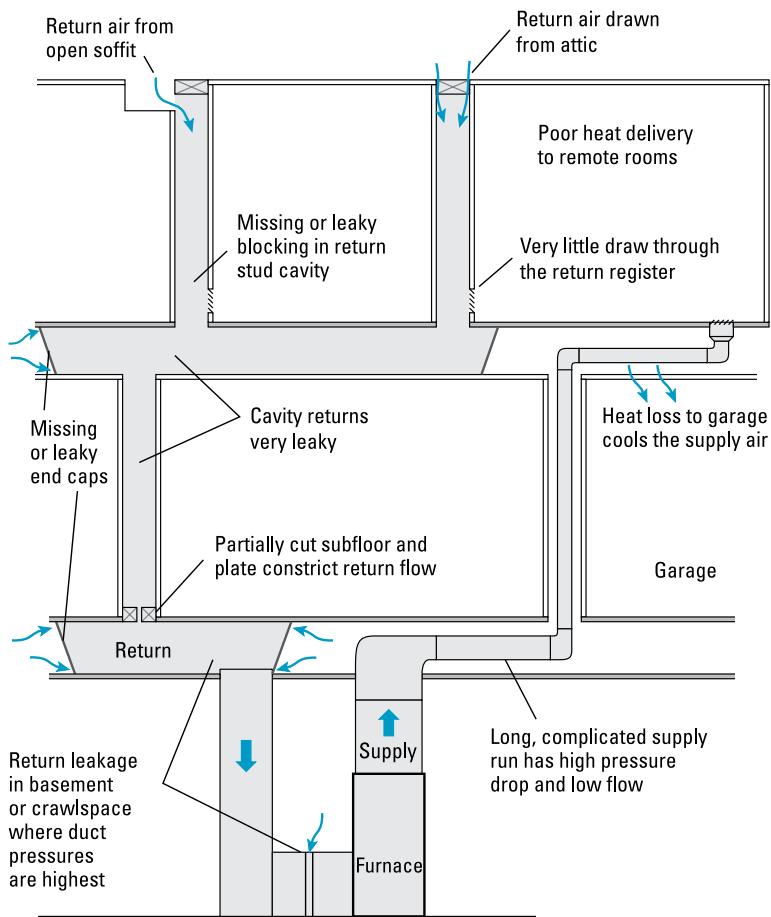
Mechanical Systems

TIP: The placement of a direct vent appliance is limited by the allowable length of the intake/exhaust pipe. Plan carefully for locating these appliances.

The direct vent water heater is completely sealed from indoor air, so backdrafting into the living space cannot occur. Similar arrangements are available for furnaces, boilers, and gas or wood fireplaces and stoves.

FIGURE 8.4

Duct problems to avoid



8

Mechanical Systems

9

Ventilation

The word “ventilation” can be interpreted in several ways. For example, it can be used to refer to the vents that provide air circulation in an attic or crawlspace. Vent systems for combustion appliances provide for removal of combustion gases. The focus of this chapter is on mechanical ventilation systems and how they can be used to reduce moisture inside our homes and improve indoor air quality. From this perspective, there are essentially two types of mechanical ventilation fans: local exhaust fans that are used to remove air from a specific location within a house (e.g., a kitchen range hood or a bath fan) and background mechanical ventilation systems that are used more generally to improve air quality in the house (also referred to as “whole-house mechanical ventilation” or “mechanical ventilation for indoor air quality”). Building codes focus on local ventilation; background ventilation is emphasized in this chapter.

Energy Code Requirements

The IECC 2009 requires outdoor air intakes and exhausts to have automatic or gravity dampers that close when the ventilation system is not operating (IECC 403.5).

The 2012 IECC requires a whole-house mechanical ventilation system that meets the requirements of the International Residential Code and specifies efficacy requirements for ventilation fans.

ENERGY STAR Homes

ENERGY STAR Homes Qualification: Ventilation

Component	Compliance	Guidelines
Whole-house mechanical ventilation	Whole house ventilation system required All exhaust fans must be ENERGY Star Qualified	Same

In order to be ENERGY STAR Qualified under Version 3, new homes must have a mechanical ventilation system designed to meet ASHRAE 62.2 2010. To meet ASHRAE 62.2 2010, the mechanical system must meet the specifications below:

- **System Type** – The ventilation system must consist of at least one supply or exhaust fan and associated ducts and controls. Local exhaust fans are permitted to be part of a mechanical exhaust system. Outdoor air ducts connected to the return side of an air handler are permitted as supply ventilation if manufacturers' requirements for return air temperature are met.
- **Ventilation Rate** – The mechanical system must deliver a minimum ventilation rate based on the home's conditioned floor area and the number of bedrooms, using the formula below.

Required CFM = $7.5 \text{ cfm} * (\# \text{ of bedrooms} + 1) + (\text{floor area} * 0.01)$

For most moderately tight homes, the ventilation rates shown below will supplement natural air leakage to a level sufficient to promote good indoor air quality.

Background Ventilation Rates

Floor Area (ft ²)	Bedrooms			
	0-1	2-3	4-5	6-7
<1500	30	45	60	75
1501-3000	45	60	75	90
3001-4500	60	75	90	105

The ventilation rates specified above are as-tested by the Rater, using a flow hood, flow grid, or other airflow measuring device. Fans are typically rated by how many cubic feet per minute (CFM) the fan will exhaust in a factory setting. Duct work, termination choices and installation may decrease the measured CFM below the factory-rated CFM. To ensure the installed fan exhausts the correct amount of CFM, it is recommended to install a fan with a rating higher than the required measured amount.

- **Control and Operation** – Continuously-operating ventilation and exhaust fans must include readily accessible override controls. Controls must be appropriately labeled.
- **Local Mechanical Exhaust** – In each kitchen and bathroom, a local mechanical exhaust system that exhausts directly to the outdoors must be installed to meet one of the following Rater-measured airflow standards below.

Local Mechanical Exhaust Rates

Fan Type	Continuous	Intermittent
Kitchen	$\geq 5 \text{ ACH, based on volume*}$	$\geq 100 \text{ CFM}$
Bathroom	$\geq 20 \text{ CFM}$	$\geq 50 \text{ CFM}$

To calculate the CFM requirement of the kitchen fan for continuous rate, use the following equation:

$$\text{Required CFM} = (5 \text{ ACH}) * (\text{Kitchen Volume}) / (60 \text{ minutes})$$

Fans are typically rated by how many cubic feet per minute (CFM) the fan will exhaust in a factory setting. Duct work, termination choices and installation may decrease the measured CFM below the factory-rated CFM. To ensure the installed fan exhausts the correct amount of CFM, it is recommended to install a fan with a rating higher than the required measured amount.

Types of ventilation systems

• **Bath fan system** – The easiest type of ventilation system to install is a simple exhaust fan system. For compliance with Version 3, exhaust fans must be ENERGY STAR qualified. Choose one bath fan to upgrade with a quiet fan (less than 1 sone). People won't use a fan that sounds like an airplane. Choose a model that is rated for continuous operation (typically 30,000 to 50,000 hours). This is to make sure it doesn't break after a year or two. The fan must be ducted to outdoors. This type of system is inexpensive; makeup air comes in through small leaks that exist even in a very tight building. It is not as effective at providing fresh air to upstairs rooms as a fully ducted supply air system, such as an energy recovery system (see below).

• **Central exhaust** – This is a middle-of-the-road type of system. You can run ducts from the bathrooms and kitchen to a central exhaust fan, which has a 24-hour timer or variable speed control. Be careful to size the ducts for adequate airflow, to balance the system properly, and to get adequate airflow from each bathroom for moisture removal. Most exhaust fans are not rated for range hood duty, so don't place the kitchen exhaust register right over the stove! This system also gets its makeup air through leaks in the building shell. Although central exhaust fans are often installed in the attic, putting the fan in the basement and exhausting out the band joist eliminates the need to insulate the ducts and places the fan in a location that stays warm, isn't dusty, and is much easier to get to for service. It also eliminates a void in the attic insulation.

• **Return makeup air** – These systems pull fresh air into the home through the return duct of a forced-air distribution system (see Figure 9.2). They are better than exhaust type systems at distributing fresh air into all the rooms in a house. In order for this approach to be effective and economical, a few issues need to be covered. The fan needs some sort of control that will run it even if there is no need for heating and cooling, or the house won't be ventilated during those times. When the heating or cooling needs are greatest, the fan will be running a lot, and the house will be overventilated unless the rate is controlled. In this case, the rate should be controlled by installing a mechanical damper on the duct that connects the system to the exterior. The position of the damper, in turn, is set by the control that provides periodic calls for ventilation air. Also, using a forced air system for ventilation means that the fan will run more, so electrical cost becomes a concern because typical furnace or air conditioner fans use a lot more power than typical ventilation fans. The operating cost can be reduced by using an electronically commutated motor (ECM).

• **Energy recovery ventilation (ERV)** — systems simultaneously pull exhaust air from the bathrooms and kitchen, and deliver fresh air to the living area and bedrooms, or to the return plenum of a wholehouse air handler (see Figure 9.3). The two air streams run through an exchange core where heat and humidity are transferred from one stream to the other. Be aware that even a large ERV may not adequately remove moisture from bathrooms if the exhaust ducts are run to many locations; it may be better to use a smaller ERV unit and to install separate bath fans for fast removal of steam. **Heat recovery ventilators (HRVs)** do not transfer moisture between the two air streams and are more appropriate in homes without air conditioning.

• **Healthier indoor air** – ASHRAE recommends that residential buildings be maintained at 30 to 60% relative humidity for optimum health. Why? Some biological contaminants thrive in low or high humidity, but most are minimized in this range. How do you control the humidity? In any climate and in any season, the first step is to control the air exchange rate. In the winter, dryness is caused by excess air leakage; when dry outdoor air is heated, the relative humidity drops. High humidity, on the other hand, is often caused by underventilation and poor source exhaust for moisture-producing activities such as cooking and bathing. Control the dryness by limiting air leakage, and control the moisture by ventilating the house. In the summer, the only way to control humidity is with mechanical dehumidification or properly sized air conditioning systems (see pages 139-140).

A typical non-ENERGY STAR home has compromised air quality due to its materials and contents. Just as mechanical ventilation provides the ability to control humidity, it also allows occupants to dilute indoor pollutants like volatile organic compounds, fumes from solvents and cleaning agents, carbon monoxide, and other compounds people shouldn't be breathing.

• **More reliable and consistent supply of fresh air** – Leaving ventilation to random air leaks doesn't work. Even leaky buildings tend to be underventilated in the spring and fall, when there's little driving force for air movement. They are also overventilated in the winter when the driving forces are large, and when it costs more money to heat up the leaking air. Leaving ventilation to operable windows and doors doesn't work. Build the house tight enough to limit the air leakage, and then give the occupants control over background ventilation rates.

• **Reduced moisture** – As well as healthier indoor air, controlled ventilation helps to limit moisture problems in the building. Water is by far the biggest threat to building durability. Exhausting water vapor as it is produced and keeping the indoor humidity reasonable is important in keeping the whole building free of moisture problems. Humid indoor air tends to find its way into building cavities and unconditioned spaces and to deposit water there. And once the building does get wet, high humidity will slow down the rate at which drying will occur. Kitchen range hoods should be exhausted to outdoors, especially if there is a gas range. Don't use dryer hose. Keep duct runs as short as possible. Of course, ventilation may not be adequate if moisture is getting into the house because of improper foundation drainage, roofing, or siding details.

• **Improved comfort** – Sealing air leaks in the building limits overventilation and drafts. Ventilation contributes to improved comfort in several ways. Controlling background ventilation rates reduces cooking odors, damp musty smells, "stale air," and elevated levels of carbon dioxide. By controlling indoor humidity, air sealing and ventilation work together to improve comfort.

• **Fewer callbacks** – A newly built house has a lot of moisture in it. Foundations, framing, drywall, plaster and paint all bring water into a new home. Depending on the weather and other conditions, there may be a lot of water. The most likely time to get a moisture-related callback is in the first winter of occupancy. When a new homeowner calls you to say "Our windows are sweating and there's mildew in the bathroom," what will you tell them? "Open a window?" How about, "Set your ventilation system to run more often (or at a higher speed)." Presto, the moisture problem is gone. Healthier, more comfortable people are less likely to complain and more likely to provide referrals.

Ducts and Controls

All exhaust fans must be ducted all the way outdoors (not into attics or other spaces). Any ducts running through unconditioned spaces must be insulated to minimize condensation. The commonly-used vinyl flex duct is not recommended. Much better air flow can be obtained with smoothwalled rigid ducts of aluminum or steel. PVC duct pipe also works well. Minimize sharp turns. Use mechanical fastenings (screws, clamps) rather than tape. Seal the ducts airtight. Noise can be minimized by using flexible mountings for fans and by attaching the ducting to the fans with short lengths of flex duct.

Ventilation air inlets must be located at least 10 feet from contamination sources such as stack, vent, exhaust hood or vehicle exhaust. Inlets must also be located at least 4 feet above grade and be provided with a rodent/insect screen.

Controls are important. It is important for HVAC Contractors and electricians to locate the override controls for continuously operating ventilation and exhaust fans in a location easily accessible to the homeowner. It is also important to properly label these controls. If controls are not properly labeled, fans may be mistakenly turned off.

New homes tend to have a lot of moisture stored in the building materials, and they also typically have chemical compounds in the air from carpets, paint, cabinetry, etc. It may be a good idea to ventilate the building at a somewhat increased rate for some time, including the first winter, when many houses experience their greatest levels of window condensation.

FIGURE 9.1
Return duct fresh air

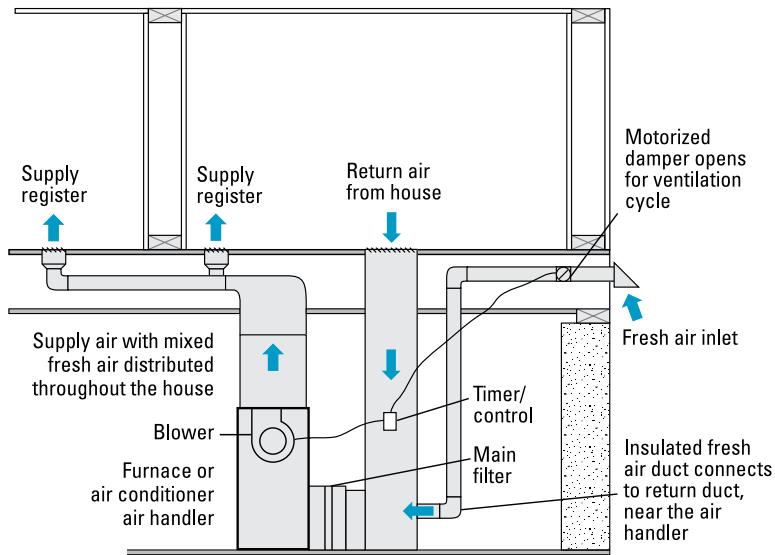
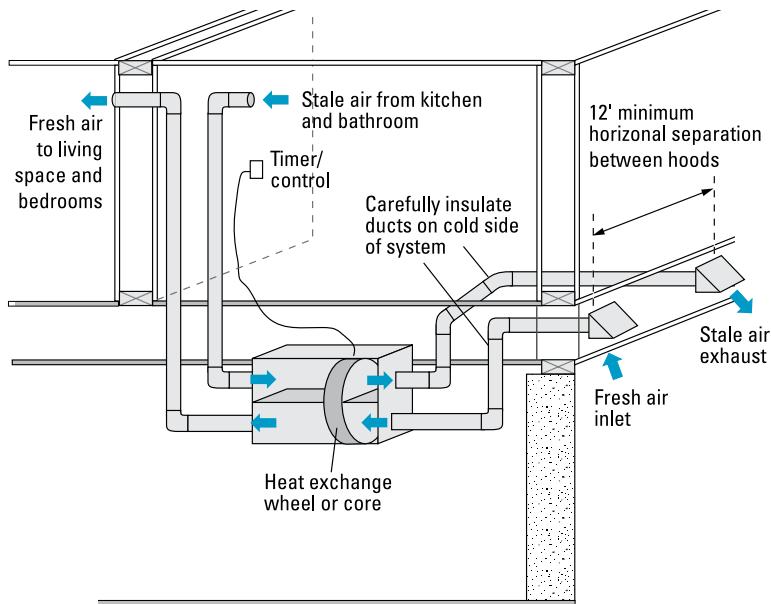


FIGURE 9.2

Energy (or heat) recovery ventilation



9

Ventilation

10

Plumbing and Electrical

Energy Code Requirements

Sealing penetrations

All penetrations through the thermal boundary of the building must be sealed (see Chapter 11). This can be done by individual subcontractors, but is more likely to be done by the builder. Electricians and plumbers can help by cutting slightly oversized holes to allow room for spray foam (see Figure 11.4), and by minimizing unnecessary penetrations.

Recessed lights

Recessed lights in insulated ceilings must be rated for Insulation Contact ("IC" rated), and must be airtight labeled. See page 31 for further details.

Piping Insulation

All hydronic pipes that are either part of a circulating hot water system or carry water that is either less than 55°F or greater than 105°F must be insulated to a minimum of R-4.

Tub/shower units on exterior walls

Be sure these have an adequate air barrier in place before installing the unit. This includes insulation and a vapor retarder as well. See Figure 11.8.

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Plumbing/
Electrical

ENERGY STAR Homes

ENERGY STAR Homes Qualification: Plumbing and Electrical

Component	Compliance	Guidelines	
Water heater, minimum efficiency	Determined by HERS compliance analysis	Size (gal.)	Energy Factor (EF)
		Gas	
		40	0.61
		50	0.59
		60	0.57
		80	0.53

ENERGY STAR Homes

ENERGY STAR Homes Qualification: Plumbing and Electrical

Component	Compliance	Guidelines for Compliance	
		Size (gal.)	Energy Factor (EF)
Water heater, minimum efficiency	Determined by HERS compliance analysis	Size (gal.)	Energy Factor (EF)
		Electric	
		40	0.93
		50	0.92
		60	0.91
		80	0.89
		Oil	
		40	0.53
		50	0.51
		60	0.49
		80	0.45
Lighting and Appliances	All refrigerators, dishwashers, ceiling fans and exhaust fans must be ENERGY STAR qualified. ENERGY STAR qualified lighting must be installed in 80% of fixtures.	All refrigerators, dishwashers, ceiling fans and exhaust fans must be ENERGY STAR qualified. ENERGY STAR qualified lighting must be installed in 80% of fixtures. Advance Lighting Package is acceptable alternative.	

Plumbing and electrical penetrations are major sources of air leakage in buildings. In addition, pipes and wires in exterior walls can make it difficult to install insulation properly. Keep plumbing out of exterior walls whenever possible (especially if the walls are being insulated with fiberglass batts). Try to run electrical wires low across walls, so it is easier to split batts on either side. If the walls are insulated with a blown- or sprayed-in insulation, there is less concern about interference. It's still a good idea to run plumbing in interior walls, or stay as close as possible to the interior in a 2x6 or larger wall, to avoid problems with freezing pipes.

Going Further

Water Conservation

Energy savings associated with service water heating can be achieved by opting for high efficiency mechanical systems (see Chapter 8) and also by reducing the amount of hot water that is actually consumed. Here are some ways to save water and the energy used to heat it.

- **Look for the Environmental Protection Agency (EPA) WaterSense label** to find efficient products (see www.epa.gov/watersense). WaterSenseSM, a voluntary partnership program, seeks to promote water efficiency and enhance the market for water-efficient products and services. Fundamentally, the goal of WaterSense is to decrease indoor and outdoor non-agricultural water use through high efficiency

products and simple practices. The program helps customers identify water-efficient products in the marketplace, while ensuring product performance and encouraging innovation in manufacturing.

- Low flow fixtures—Showerheads with a 2.0 gallon/minute (GPM) capacity conserve water but still have enough flow for a comfortable shower. Kitchen faucet aerators should be rated at 1.5 GPM, bathrooms at 1.0 GPM.
- Water saving appliances—Front-load washing machines use an average of 10 gallons per wash less water than similarly sized top-load washing machines. Such machines save electricity, detergent, and the energy used to heat wash water. They also spin the clothes more thoroughly dry than conventional machines, saving even more.
- House design—Plan for centralized plumbing by locating the kitchen, bathrooms, the laundry room and the water heater in a common vertical space. By grouping and stacking in this manner, hot water can be readily delivered to the locations where it is required, resulting in less water use and a reduction in heat loss through the hot water pipes.
- Distribution—if long runs from the water heater to the plumbing fixtures cannot be avoided, consider installing a parallel pipe (or homerun) system to reduce pipe losses by providing a more direct connection between the hot water source and the fixture (see Figure 10.1).

Hot Water Circulation

In large houses, recirculating hot water pipe loops are sometimes used to keep hot water close to every fixture. As an alternative, a demand recirculation system can be used to reduce “standby” losses. These systems rapidly replace water in the pipe with hot water before the tap is opened. Although there is a slight delay in the delivery of hot water to the fixture, the energy savings compared to the continuously circulating loop is significant.

Heat Recovery

Most of the hot water used in a home goes down the drain with plenty of heat still left in it. A drain water heat recovery device (see Figure 10.2) can capture some of that heat and send it back to the water heater using no electricity and with no moving parts. These systems work best when there is a prolonged usage of hot water (i.e., when the hot water is draining at the same time that the water tank is filling). A drain water heat recovery system is typically installed in the drain line below the most commonly used shower, or on the main drain just before it exits the house. Cold water bound for the water heater is preheated as it circulates around the drain line, picking up heat from the drain water.

FIGURE 10.1
Home run plumbing

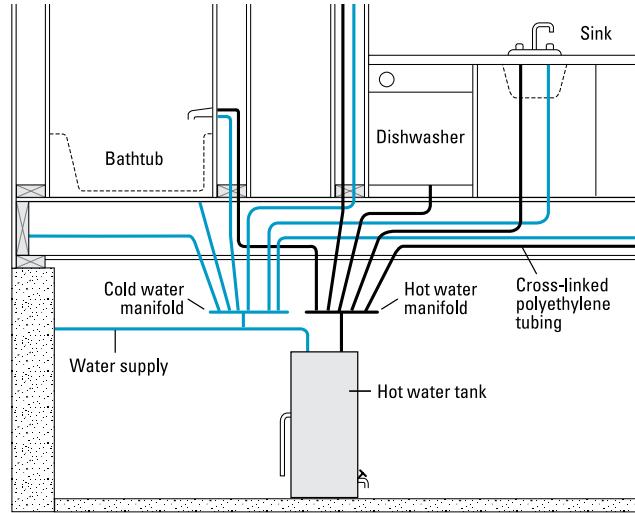
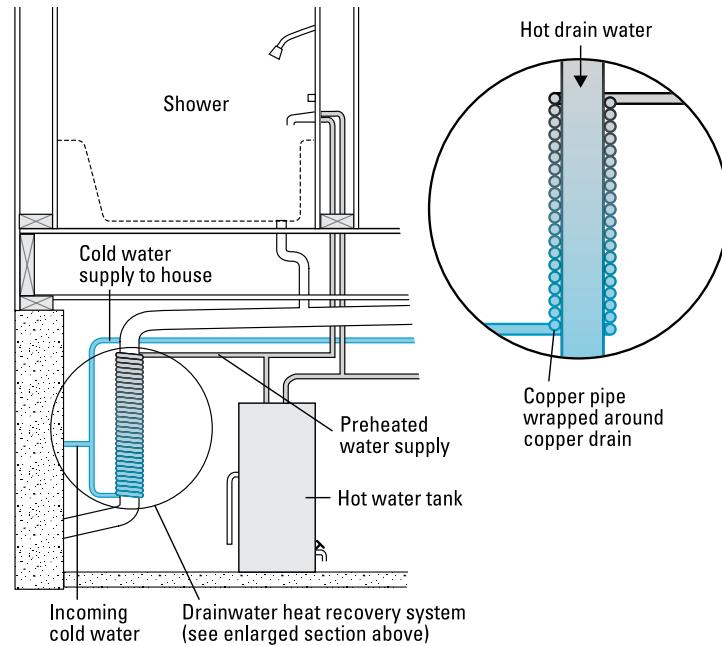


FIGURE 10.2
Drainwater heat recovery system



Piping arrangement shown for illustrative purposes only. Please consult manufacturer's recommendations and local codes for details of piping requirements.

11

Air Sealing

Energy Code Requirements

The code has a list of areas that must be sealed (IECC 402.4), and gives examples of sealants to use. The leaks to be sealed include leaks between conditioned and unconditioned space, and leaks between conditioned space and outdoors. Note that fiberglass batts do not stop air and cannot be used as a sealant.

The IECC requires air sealing anywhere there are openings between conditioned and unconditioned space. See Appendix C - Air Barrier and Insulation Inspection Criteria. The following is a list of some of the most important locations:

- **Between wall and roof or ceiling; wall and floor; between wall panels.** These are often some of the largest leaks in a house. They typically occur in places where cavities between studs or joists connect a conditioned space to an attic or basement area. “Draftstop” blocking is the simplest way to deal with these leaks. Typical examples are shown in Figures 6.11-6.18.
- Penetrations of utility services through walls, floors, ceiling/roofs, wall plates. Plumbing, electrical, duct and chimney chases are examples of these leaks. See Figures 5.7, 6.8, 6.11-6.12, 6.14, and 11.1-11.7.
- Door and window frames—Rough openings should be sealed to frames with low expansion foam, caulking, or backer rod and caulk. Be careful, even with low expansion foam; if you fill large spaces it can still push out the jambs. To control this, don’t worry about filling the entire space; just bridge the gap between the rough opening and the jamb. See Figures 7.2 and 7.4.
- At foundation/sill—The numerous framing members between the top of a foundation wall and the toe plate of the wall above allow significant leakage. The weight of a house is not enough to force these pieces together. Foam “sill seal” between the foundation and sill is commonly used. In addition, seal the band joist area according to Figure 6.1 or 6.2.

Note: vertical “steps” in the foundation height (where the grade changes) need special attention to avoid air leakage. Sill sealer will not generally stop air leakage in these locations.

- **Around/behind tubs and showers**—These leaks cause heat loss, and are common causes of comfort complaints and freezing pipes. Bathrooms over garages are especially prone to such problems. See Figures 11.7-11.8.

- **At attic and crawlspace panels**—Attic scuttles, pull-down stairs, access doors through knee walls into unheated attic spaces, and access from a conditioned basement space into a crawlspace all need weatherstripping as well as insulation. See Figure 11.10.

- **At recessed lights**—The requirements for recessed lights are given on page 103, and Figure 11.9. Durable caulking, gaskets, tapes and/or housewraps should be used to seal these areas. The code also says to “allow for differential expansion and contraction of the construction materials,” for example where wood, metal, concrete and/or plastic join each other. If you use housewrap for an air barrier, it should be installed according to manufacturer’s instructions. These instructions generally call for careful detailing and taping of all seams, including—but not limited to—the edges around window and door openings, at the sill area, and where exterior walls meet roof lines. Also note that housewrap generally does not address many of the most significant leakage pathways in a house (which are typically found in attics and basements). See page 140 for more information about bulk water control.

11

Air Sealing

Air Sealing Verification

The 2009 IECC requires that air sealing and insulation installation be verified through either a blower door test or visual inspection. Visual inspection is no longer an option for air sealing verification in the 2012 IECC.

Leakage Testing

If the testing option is chosen, tested air leakage must be less than seven air changes per hour (ACH) when tested with a blower door at a pressure of 33.5 psf (50 pa). Testing must occur after rough in and after installation of penetrations of the building envelope and be conducted according the specifications below:

- Exterior windows and doors, fireplace and stove doors must be closed, but not sealed;
- Dampers must be closed, but not sealed, including exhaust, intake, makeup air, backdraft and flue dampers;

Interior doors must be open;

- Exterior openings for continuous ventilation systems and heat recovery ventilators must be closed and sealed;
- Heating and cooling systems must be turned off;
- HVAC ducts must not be sealed; and
- Supply and return registers must not be sealed.

Visual Inspection

If the visual inspection option is chosen for verifying air sealing and insulation installation, each item listed in the checklist below must be field verified. Also see Appendix D.

The 2012 IECC requires all buildings to be tested and verified as having an air leakage rate of three air changes per hour or less, when tested with a blower door at a pressure of 33.5 psf (50 pa).

11

Air Sealing

Air Barrier and Insulation Installation Inspection Checklist

COMPONENT	CRITERIA
Air barrier and thermal barrier	Exterior thermal envelope insulation for framed walls is installed in substantial contact and continuous alignment with building envelope air barrier. Breaks or joints in the air barrier are filled or repaired. Air-permeable insulation is not used as a sealing material.
Ceiling/attic	Air-permeable insulation is inside of an air barrier. Air barrier in any dropped ceiling/soffit is substantially aligned with insulation and any gaps are sealed. Attic access (except unvented attic), knee wall door, or drop down stair is sealed.
Walls	Corners and headers are insulated. Junction of foundation and sill plate is sealed.
Windows and doors	Space between window/door jambs and framing is sealed.
Rim joists	Rim joists are insulated and include an air barrier.
Floors (including above-garage and cantilevered floors)	Insulation is installed to maintain permanent contact with underside of subfloor decking. Air barrier is installed at any exposed edge of insulation. Insulation is permanently attached to walls.
Crawl space walls	Exposed earth in unvented crawl spaces is covered with Class I vapor retarder with overlapping joints taped.
Shafts, penetrations	Duct shafts, utility penetrations, knee walls and flue shafts opening to exterior or unconditioned space are sealed.
Narrow cavities	Batts in narrow cavities are cut to fit, or narrow cavities are filled by sprayed/blown insulation.
Garage separation	Air sealing is provided between the garage and conditioned spaces.
Recessed lighting	Recessed light fixtures are air tight, IC rated, and sealed to drywall. Exception—fixtures in conditioned space.
Plumbing and wiring	Insulation is placed between outside and pipes. Batt insulation is cut to fit around wiring and plumbing, or sprayed/blown insulation extends behind piping and wiring.
Shower/tub on exterior wall	Showers and tubs on exterior walls have insulation and an air barrier separating them from the exterior wall.
Electrical/phone box on exterior walls	Air barrier extends behind boxes or air sealed-type boxes are installed.
Common wall	Air barrier is installed in common wall between dwelling units.
HVAC register boots	HVAC register boots that penetrate building envelope are sealed to subfloor or drywall.
Fireplace	New wood-burning fireplaces have gasketed doors and outdoor combustion air. Fireplace walls include an air barrier.

It is interesting to note the extent to which code requirements for air sealing and fireblocking overlap: “Fireblocking shall be provided to cut off all concealed draft openings (both vertical and horizontal)...” (IRC Section R602.8). Fire is much the same physically as heat loss, except it’s much faster and more destructive. Specific fireblocking requirements parallel the requirements for air sealing that are outlined in the IECC, calling for draft stops that address the following:

- Hidden leaks in walls that intersect with attics and/or basements, including the openings around and associated with chimneys, ducts, vents, furred ceiling spaces, and the like (chases and cavities).
- Leaks that result from a change in ceiling height (e.g. soffits, drop ceilings).
- Leakage pathways associated with stair stringers.

In general, wherever draftstopping makes sense from an energy perspective, it is probably also required by fire code. Fire code however, may call for draft stops in places that do not align with the thermal boundary (such as between two heated floors). With respect to energy efficiency, these stops are less of a concern.

Fireblocking and air sealing requirements not only overlap, but are also complementary. With fireblocking, the emphasis is placed on selecting an appropriate material to serve as a draft stop (acceptable materials include 2" of lumber, 3/4" nominal plywood or particle board, 1/2" drywall or 1/4" cement board). Energy code complements this requirement by calling for the perimeters of these stops (or baffles) to be sealed to the surrounding surfaces. Both steps are required to achieve a complete and effective air barrier.

It is important to note that there is also one way in which these two sections of the code are not complementary. In addition to the items listed above, mineral and glass fiber materials are also allowed for use as fire stops. Fibrous materials however, are ineffective at stopping air. Consequently, they should not be used where air sealing is required.

ENERGY STAR Homes

ENERGY STAR Homes Qualification: Air Sealing

Component	Compliance	Guidelines
Maximum allowable air leakage rate	Determined by HERS compliance analysis	4 Air Changes Per Hour (ACH) at 50 Pascals (test pressure)
Thermal Enclosure Checklist	Checklist details air sealing requirements. Continuous air barrier must align with insulation. See figures 11.4–11.11.	Same

Air sealing is an important part of energy efficient construction, but does not neatly fit into any one category of subcontractor. Some air sealing is done most easily by framers as they put the pieces together. Some can be done by drywall crews. Some insulation contractors specialize in air sealing. But it is the builder who is ultimately responsible to see that adequate air sealing is done by the right people at the right times. If planned thoughtfully and done at the right stages of construction, most air sealing can be done with very little added expense. If you pay attention to the air sealing requirements of the energy code, you will already be well on the way to building an ENERGY STAR Qualified New Home.

The concept of air sealing is to provide a continuous air barrier all the way around the house. It does not mean hermetically sealing the building—there will always be leaks and cracks where air can get in and out. It does mean thinking about what material is going to stop indoor air from mixing with outdoor air (see pages 112 and 117). Note that in all drawings, the dotted line (in color) represents the primary air barrier.

Here are some hints to help with air sealing:

- **Get the biggest leaks first.** This may seem obvious but it's not. There's little point in caulking the small cracks or sealing electrical boxes if you have a plumbing chase or floor system that leaves a hole of ten, or twenty, or forty square feet, straight into an attic. A simple rule of thumb is: first seal up the ones you can crawl through; then seal up the ones a cat can crawl through; then go after the details.
- **Get the least expensive ones next.** Think about ways that you can build air sealing into tasks you are doing anyway, with materials that are on hand. Some examples: specify drywall adhesive or acoustical sealant on top plates and end studs of partition walls. Specify construction adhesive on all layers of floor framing instead of just the subfloor. Use leftover scraps of rigid insulation to block off chases or floor cavities. Then, before drywall is hung, have one person go around with a foam gun and seal up all the small wiring and plumbing penetrations in top plates or end studs, as well as the window and door frames. If you do whatever you can in two or three hours, it will make a big difference in most houses.
- **Once the drywall is up, all the leaks become invisible.** They don't go away—they just disappear so you can't see them. Walk through the house before the drywall crew shows up, imagine that only the ceiling sheetrock has been applied and ask yourself, "Can I stick my hand past the sheetrock, through the insulation and into an attic space from here?" Then imagine the sheetrock has been applied only to the walls and ask yourself a similar question: "Can I stick my hand through the insulation to the outside or to an unconditioned space (e.g., a garage) from here?" If the answer to either question is "Yes," then draft stops or blocking should be added before the

drywall is hung. It will never happen later. (Of course if you are using "airtight drywall approach" then the drywall itself may be a substantial component of your air barrier. See Airtight Drywall Approach section (below) and Figures 11.1-11.3 for more information.)

- **Insulating and air sealing are separate issues.** Though some insulation materials resist the flow of air more than others, the choice of insulation material alone does not ensure air tightness. Proper detailing is important. Many air leaks occur in locations other than where the insulation is typically installed (for example, under a bottom wall plate, or around a window). No insulation will adequately seal large chases. Even when using a material like spray foam, care should always be taken to identify and address remaining leakage pathways.
- **Interior wood finishes should be backed by a separate, continuous air barrier.** Wood planking, tongue and groove wood products, etc. allow significant quantities of air to pass through their assemblies. These assemblies should never be left open to insulated building cavities that are part of the thermal boundary. Back these finishes with a continuous air barrier, such as drywall or rigid insulation that is sealed at the seams.

Other techniques

Much of the focus on building very tight buildings has historically concentrated on interior air barriers, particularly sealing and detailing of polyethylene vapor retarders as the primary air barrier. This should not be done in any house that has air conditioning. Use a material that's already there, such as the drywall or exterior sheathing, as the primary air barrier. The use of "airtight drywall," for example, can significantly enhance the air tightness of a home at little extra cost.

Airtight drywall approach

If you use adhesive or acoustical sealant to attach drywall to top plates and end studs of partition walls, where they meet insulated walls and ceilings, this helps keep the air in the wall from getting "out." Add adhesive around window and door rough openings and caulk around electrical boxes to complete a reasonable air barrier. At a minimum, specify adhesive on all top plates of walls that intersect insulated ceilings. If your drywall crew doesn't want to do that, you can squeeze a thick bead of acoustical sealant in these areas, and you have an instant gasket. See Figures 11.1-11.3 for more about "airtight drywall approach."

What if I build the house too tight?

There is no way to build a house "too tight." Tight is good. You can build an underventilated house (see page 121), but not if you put in a ventilation system. Tight houses save the customer money and reduce callbacks, but you must install ventilation. Mechanical ventilation is strongly recommended for all new homes and is required for all ENERGY STAR homes, because it's the only way to ensure

an adequate level of air exchange, regardless of how tight the house is. And the ventilation air will cost less to heat than a leaky house, every time.

Going Further

In addition to energy savings, you get other important advantages by building a tighter house. Tight construction can help reduce:

- Ice dams**—Most discussion of ice dam prevention concentrates on passive ventilation of the roof sheathing, such as continuous soffit and ridge vents. Ice dams are caused by heat in the attic melting snow from the bottom. Although ventilation does dilute heat that gets into the attic, reducing the flow of heat is more important. Sealing up air leaks into the attic is the most important factor in reducing ice dams, followed by keeping HVAC out of the attic, and proper insulation.
- Moisture in building frame**—Most of the focus on preventing water vapor from getting to cold surfaces (wall sheathing, attic structures, etc.) has traditionally centered on vapor retarders. Vapor retarders are important; but it has been shown that, in the average home, over 100 times more water vapor is carried into these spaces by leaking warm, moist air, than by diffusion. Seal up the air leaks (and install mechanical ventilation) to reduce moisture that causes structural damage and health risks. See the EEBA Builder's Guide for more on the relationship between vapor diffusion retarders and air flow retarders, and the mechanisms of vapor diffusion.
- Freezing pipe problems**—Most pipe freeze-ups are a result of moving cold air, not just cold temperatures. Of course it is important to keep pipes on the warm side of insulated assemblies. However, it is also critical to define a good air barrier and keep the pipes on the “inside.” Many pipe freezes occur in areas such as garage ceilings, kneewall floors, and other places where the air barrier is typically not well defined. See Figures 6.12 and 6.15.
- Insects and rodents**—Of course air sealing alone won't keep vermin outside the building, but it will greatly reduce their access to the living space. Be careful about exterior rigid insulation on foundations, which can provide invisible insect access into the house (see page 45).
- Fire spread**—In general, efforts devoted to air sealing a house will also improve fire safety. See page 113 for more information.

A wide variety of materials can be used to air seal a building. Material compatibility, the size and location of the leak, ultraviolet and/or high heat exposure, etc. should all be considered when selecting the products to be used. Important material-specific considerations are outlined in the following table.

ENERGY STAR Homes

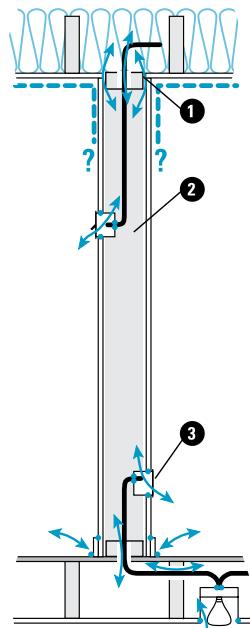
ENERGY STAR Homes Qualification: Mechanical systems

Component (Products)	Compliance
Gaskets (backer rod, sill seal, EPDM gaskets, Trelleborg, Willseal 600)	<ul style="list-style-type: none"> Gaskets are commonly used around windows and doors and between the foundation and mud sill, but can also work well in most other areas where a seal is required More tolerant of differential movement of building assemblies than foam or caulk Pre-formed EPDM gaskets are expensive, but can be very effective for sealing sill plates, drywall-to-plate connections, and other areas
Low Expansion Foam (Pur Fil, Great Stuff)	<ul style="list-style-type: none"> Ideal for sealing gaps that are between 1/4" and 1/2" (e.g., around windows and doors, wiring holes, drywall cutouts, etc.) Not rated for use in high temperature locations Difficult to clean up; not for use on finish materials Cans that are equipped with a reusable gun are the easiest to use and the best value Protect from UV exposure
High Expansion Foam (Zero Draft, Froth Pak)	<ul style="list-style-type: none"> Ideal for sealing locations with multiple leakage pathways, such as a band joist, top plates in an attic (after the drywall has been installed), a chase that is obstructed by ducts, pipes and/or wires, and other hard-to-reach areas Do not use around windows and doors Protect from UV exposure
Acoustical Sealant (Quiet Seal, Tremco)	<ul style="list-style-type: none"> Durable caulk that stays flexible and accommodates differential movement of building assemblies Can be used to seal drywall to framing (“air tight drywall approach”) Only sealant that permanently adheres to polyethylene For indoor use only
100% Silicone Caulk, Urethane Caulk	<ul style="list-style-type: none"> Durable caulk for indoor or outdoor use Use to seal gaps that are up to 3/8" (see manufacturer's instructions) Not paintable Caulking should never be used on the building exterior as a barrier to rainwater entry; it's not dependable for that application
Siliconized Acrylic Caulk	<ul style="list-style-type: none"> Use to seal gaps that are up to 3/16" Less flexible and durable than 100% silicone, but paintable Use only where painting is required
Fire-rated Sealants (fire-rated caulking, furnace cement, high heat mortar)	<ul style="list-style-type: none"> Non-combustible Use to seal gaps around chimney/fluepipes Wide variety of products, available in tubes or tubs
Rigid and Semi-Rigid Blocking (cardboard, foil-faced bubble pack or foam board insulation, wood, sheetrock, etc.)	<ul style="list-style-type: none"> Blocking is needed to seal bypasses/chases that are too big to seal using any of the materials listed above Perimeter of blocking should be sealed to surrounding materials with foam or caulk Metal flashing, sheet metal and/or foil-faced rigid fiberglass can be used to seal large leaks around chimneys or fluepipes Wood, sheetrock, cement board or sheet metal must be used to seal bypasses/chases that are part of a fire-rated assembly (between dwelling units or between a dwelling unit and an attached structure that is categorized as a different type of occupancy)

FIGURE 11.1

Strategic sealing: interior partition wall intersection with attic

Poorly defined air barrier



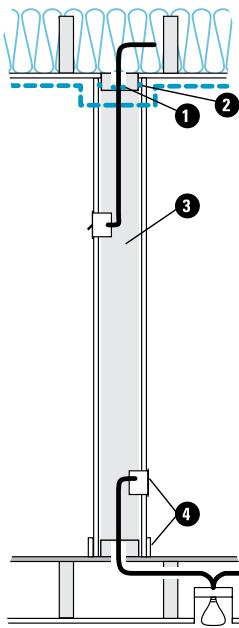
11

Air Sealing

A lot of material and effort may be needed with no guarantee that leakage will be stopped.

- 1 Air barrier is broken at attic/wall intersection. Top plate shrinks away from drywall when wood dries
- 2 Wall cavity serves as duct linking unconditioned attic to rest of house
- 3 Many potential air leakage paths. Sealing one may simply shift leakage to another.

Well-defined air barrier



Sealing the top plate, before the drywall is hung, requires little effort and completes the air barrier at the insulated ceiling.

- 1 Seal top plate penetrations
- 2 Seal drywall to framing—“airtight drywall approach”
- 3 “Inside air”
- 4 No need to seal drywall penetrations in interior wall

FIGURE 11.2

Sealing intersections at the ceiling

Seal wall drywall to top plate with adhesive or acoustical sealant

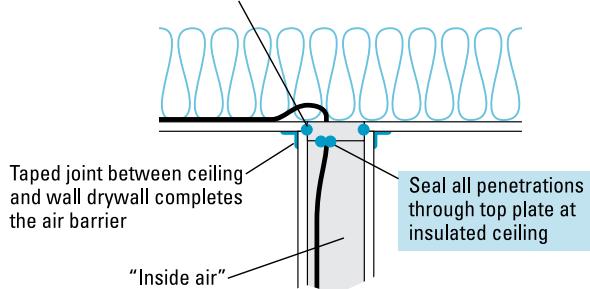
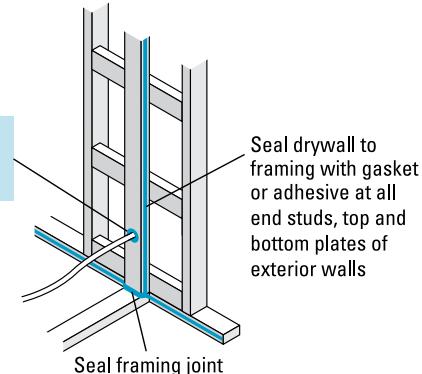


FIGURE 11.3

Sealing intersections at exterior walls

Seal all penetrations through end stud into an exterior wall



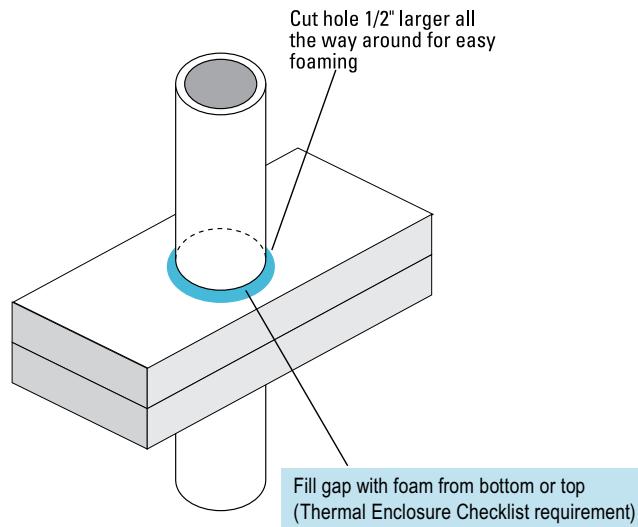
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Air Sealing

The sealing techniques shown in Figures 11.1 to 11.3 are the fundamental components of the “airtight drywall approach” (which includes airtight or sealed electrical boxes, and carefully sealed band joists as well). Even if you are not using a complete “airtight drywall” system, specifying adhesives at top plates and end studs will significantly reduce air leakage. Be especially careful at the intersections where multiple partition walls meet each other at insulated ceilings.

FIGURE 11.4

Sealing plumbing vent pipes



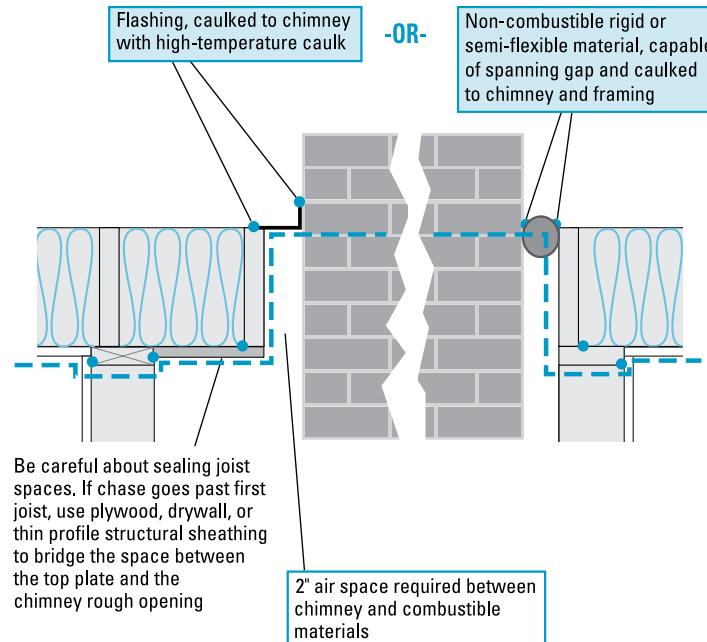
Plumbing vent pipes can be sealed with foam from above or below. Long, straight pipe runs may be sealed using a rubber boot or roof boot to address the movement of pipes relative to the framing. This requires coordination with the plumber, to install it as the pipe goes in.

11

Air Sealing

FIGURE 11.5

Chimney Chases



NOTE: Chimney/flue shaft seal is a Thermal Enclosure requirement. Duct chases can be just as large a leak, but ducts can be sealed directly to framing with spray foam.

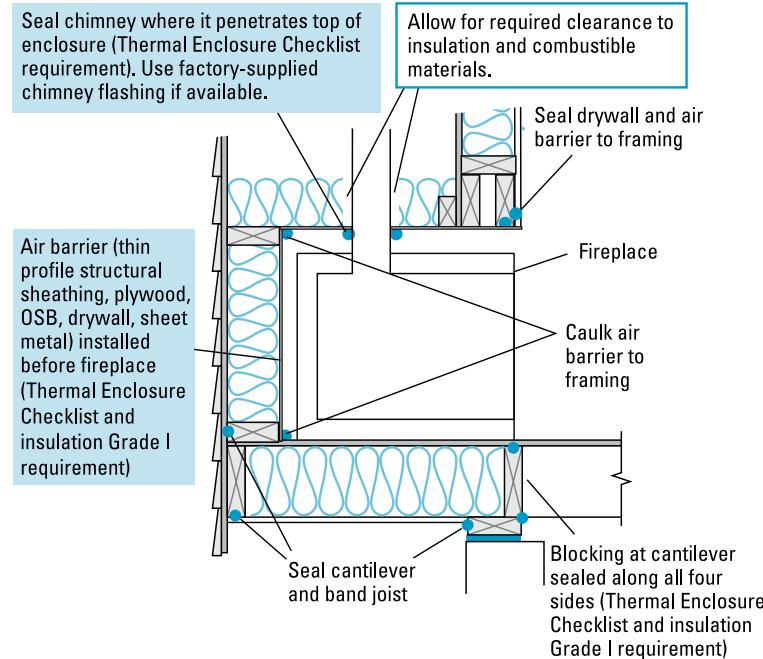
Unsealed chimney chases are often one of the largest leaks in a house. Be careful to keep combustible materials at least 2" from the chimney, and use high-temperature silicone caulking or firestop caulk. Many prefabricated chimneys have draft blocking and/or insulation guard kits available to fit them; follow the manufacturer's instructions.

11

Air Sealing

FIGURE 11.6

Air sealing fireplace enclosures



11

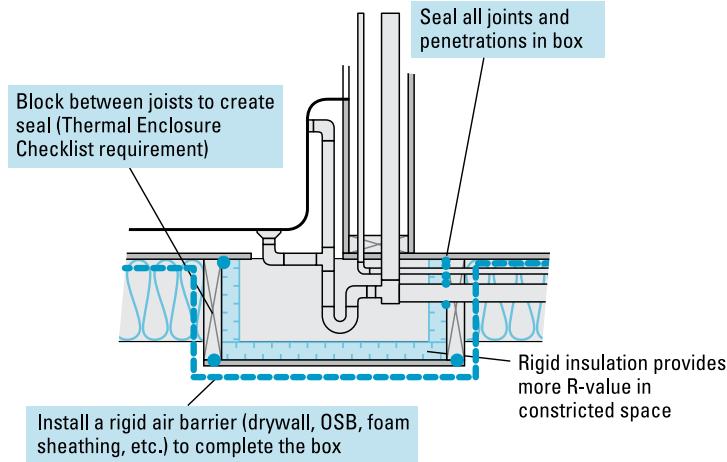
Air Sealing

TIP: In some instances with complex framing, such as a home entertainment center recessed above the fireplace cavity, it may be simpler to use the exterior sheathing as the air barrier. However, it is still necessary to seal the top of the chase as shown in Figure 11.5.

Be sure to install the air barriers and do the sealing before the fireplace is set in place.

FIGURE 11.7

Boxed-in tub in insulated floor

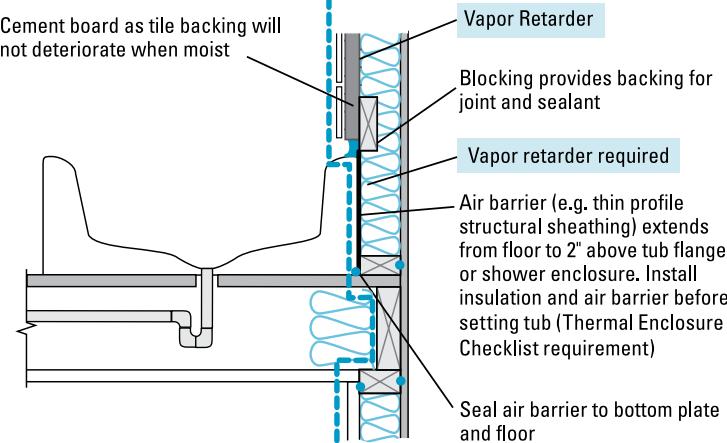


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Air Sealing

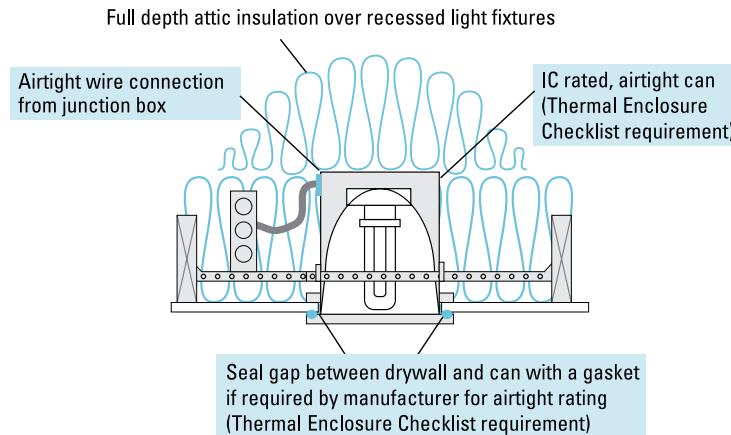
FIGURE 11.8

Sealing tub and shower enclosure



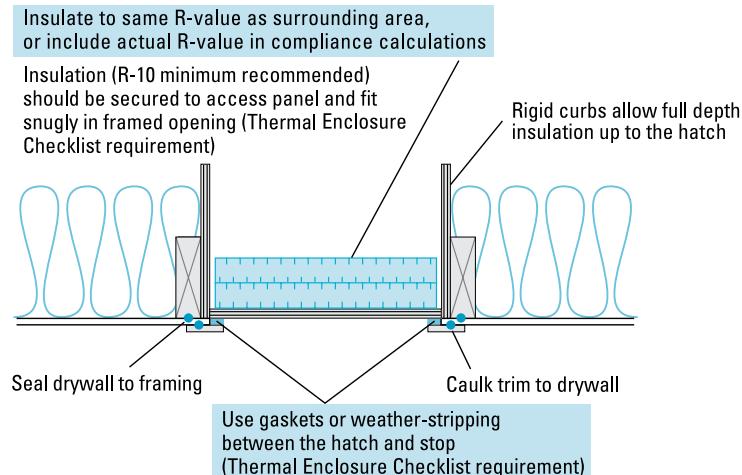
CAUTION: Do not use standard or moisture resistant drywall as a tile backing material in this application. They deteriorate when they get wet.

FIGURE 11.9
Recessed lights



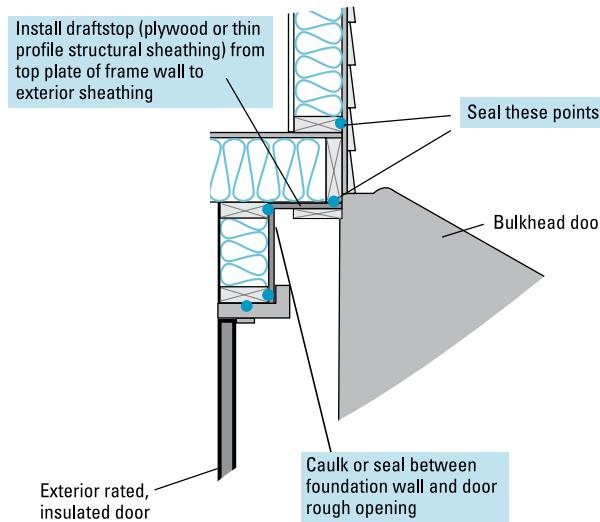
CAUTION: Even with careful detailing, a cavity-insulated frame wall is a poor choice for insulating foundation walls. All or most of the insulation should be continuous and sealed directly to the foundation (see Figures 5.4-5.6).

FIGURE 11.10
Attic hatch



TIP: If the attic is accessed from an unheated space, like a garage, hatch air sealing and insulation are not required.

FIGURE 11.11
Bulkhead door detail



CAUTION: This area may contribute to air leakage even in an uninsulated basement.

12

Insulation

Energy Code Requirements

Insulation R-values

The R-values of insulation in any part of the thermal boundary are defined by your compliance analysis. Whether it is a prescriptive table, a REScheck printout or any other approach, the minimum R-value for each component is specified and documented with the building permit application (IECC Section 103). If, during construction, you want to substitute a lower than specified R-value for a particular component (wall, ceiling, etc.), you must redo the compliance analysis to make sure the change does not result in non-compliance, and re-submit the paperwork with the new specifications. You may have to substitute higher R-values somewhere else in the building to compensate, or choose a different method of determining compliance.

Proper installation

All R-values are based on proper installation. For fiberglass batts, this means:

- **Full loft**—Insulation should be fluffed to its full thickness, not compressed, and not rounded or scalloped at the edges.
- **Fill the cavity**—Insulation should be in snug contact with all wall studs, plates, sheathing and drywall. In ceilings and floors, it should be in contact with the drywall or subfloor, and extend all the way to the joists on both sides without gaps (see Figure 12.2).
- **Cut around obstacles**—Insulation should be split around wires and small pipes, cut out around electrical boxes, larger pipes and other obstacles, and split over cross bridging in floors. Never stuff insulation in to get it to “fit” (see Figure 12.1).

Refer to industry standards such as *Fiber Glass Building Insulation: Recommendations for Installation in Residential and other Light-Frame Construction* (North American Insulation Manufacturers Association), or *Standard Practice for Installing Cellulose Building Insulation* and *Standard Practice for the Installation of Sprayed Cellulosic Wall Cavity Insulation*.

(Cellulose Insulation Manufacturers Association). These resources are listed in Appendix B.

Documentation of R-values (IECC 303.1.1 and 303.1.2)

Many common insulation products have R-value markings right on them. Faced and unfaced fiberglass batts, and rigid foam insulation must be installed so the markings are visible to the building inspector. If you are using blown- or sprayed-in insulation such as cellulose, spray foam, or blown fiberglass, the installer should provide a certificate showing installed thickness, settled thickness, the square feet of coverage, the number of bags (or amount of material) used, and the net installed R-value. For blown-in attic insulation, “tell-tale” inch markers are also acceptable, provided they show installed thickness and settled thickness (a minimum of one marker per 300 square feet of attic is required.)

Credit for “raised truss” construction (IECC 402.2.1)

Insulation in flat or cathedral ceilings is assumed to be compressed over the exterior walls, as is typical (Figure 12.4). If you can install the insulation in such a way as to get the full R-value of insulation all the way to the outside of the exterior wall, then you can take credit for “raised truss” in your compliance analysis. In the prescriptive method a raised truss or its equivalent allows you to substitute R-30 insulation when R-38 is specified, or R-38 for R-49. For the other methods, it gives you some credit toward your point score. This does not mean you have to use a raised heel truss to get this credit; examples of alternative methods are shown in Figures 12.5-12.7, 12.9. Depending on the roof geometry and the care of installation, you may not even need to modify the framing. For example, a high-pitched roof truss with a large overhang may not need any special treatment to achieve the full R-value at the eaves.

Vaulted Ceiling Exemption

Vaulted ceilings are permitted a reduction in the required insulation level to R-30 (all Climate Zones) when the roof/ceiling assembly does not allow sufficient space for the required insulation. This exemption is limited to 500 square feet or 20% of the total ceiling area, whichever is less.

Access Openings

Attic hatches, scuttles, pulldown stairs, etc. must be insulated to the same R-value as the surrounding area, or the actual R-value must be accounted for in your calculations (see Appendix A).

Steel Framing

Steel is an excellent conductor of heat. Consequently, the effective performance of insulation in steel framed building assemblies is reduced

dramatically. Cold interior surfaces near the steel studs bring an increased potential for condensation and mold growth. Code accounts for the thermal “bridging” that results from the use of steel framing by making insulation requirements more stringent. The easiest way to meet these requirements is to add a layer of continuous, rigid insulation that covers all the framing and acts as a thermal “break” (see IECC Table 402.2.5 for insulated steel and wood wall equivalencies).

Eave Baffle

Vented attics with air-permeable insulation must have a baffle, of any material, installed adjacent to soffit and eave vents. Baffles must maintain an opening equal to or greater than the size of the vent and must extend over the top of the attic insulation.

ENERGY STAR Homes

ENERGY STAR Homes Qualification: Insulation

Component	Compliance	Guidelines
Insulation R-values	Determined by HERS compliance analysis	Insulation levels must meet or exceed the minimums established by the 2009 IECC Grade I installation quality (see below)
Thermal Enclosure Checklist	Insulation must be installed in full contact with continuous air barrier	Same

Proper application of insulation materials is critical to the success of any ENERGY STAR Qualified New Home. In response to this fact, the national Home Energy Rating System (HERS) industry has developed guidelines for assessing insulation installation quality. These guidelines (summarized below) are an integral part of not only the HERS industry, but also the ENERGY STAR Qualified New Homes program; the installation grade must be factored into the HERS analysis that is used to determine performance-based compliance. A Grade I installation is required when using the prescriptive compliance option.

- **Grade I**—Near perfect installation quality (full height, full width, full depth, no voids, no gaps, cut to fit neatly around any intrusions, etc.). Grade I is also used to describe insulation that is generally installed according to manufacturer’s instructions and/or industry standards. There are other location-specific requirements for Grade I for walls, ceilings and floors.

- **Grade II**—Average installation quality with a minimum of voids and

compression. Insulation may have occasional defects such as gaps around wiring, electrical outlets, plumbing and other intrusions. There are other location-specific requirements for Grade II for walls, ceilings and floors.

- **Grade III**—Poor installation quality, which may include gaps, voids, compression, rounded edges or “shoulders,” incomplete fill, etc.

Here are some additional guidelines:

- **Faced batt insulation** may be installed by stapling the flanges to either the sides or face of the framing that runs along the edges of the batt (see Figure 12.3). When side stapling, be sure to staple the tabs neatly (no buckling), and to compress the batt only at the edge of each cavity and only to the depth of the tab itself. Face stapling is generally considered to be preferable to side stapling from an energy perspective, but the performance difference is likely to be small. Face stapling is often disliked by drywall installers. To lessen the potential impact, be sure to set staples firmly into the studs, avoid pulling fiberglass fibers over the face of the studs, and mark the stud locations on the floor.

- **High density fiberglass batts** such as R-13, R-15, and R-21 get a higher R-value in the same cavity. They also tend to be stiffer, and fluff up so it is easier to get a good fit without compression. Although not an ENERGY STAR requirement, it is a good idea to use high density batts if you are using fiberglass, and you can get credit for the added R-value in the code analysis as well.

- **Beware** of manufacturer claims representing R-values of particular products. “Equivalent” R-value may not be a legitimate descriptive term. This caution applies especially to alternative insulation materials, such as “radiant”/reflective products, or to systems (such as structural insulated panels, insulating concrete forms, or special concrete products) that claim to have an “equivalent” R-value due to some added quality, such as air tightness or thermal mass, that should not be included in the actual R-value.

- **Air barriers and eave baffles to prevent wind washing** (Grade I requirement)—No matter how well you install insulation, cold air washing through it will not only severely compromise its effectiveness, but also increase condensation potential by cooling the vapor retarder. Eave baffles made of cardboard or foam board are essential (see Figures 12.5, 12.6 and 12.8); if the baffle extends above the top of the insulation, no vent chute or “propavent” is required. Also vulnerable are exposed insulated walls, such as attic knee walls (Figures 6.15, 6.16 and 6.18). Cover the exposed fiberglass on the attic side with a vapor permeable air barrier such as housewrap, polystyrene foam,

drywall, or similar material. Floor insulation over piers, cantilevers and the like should also be sealed to prevent outside air from circulating into the insulation (Figures 6.11 and 6.12). Flat or sloped attic insulation need not be covered, but baffles should be provided near eaves (see Figures 6.16, 6.17, and 12.5, 12.8, and 12.9).

- **Cavity fill types that improve air tightness**—Some insulation materials can help. See page 36.

- **Avoid strapped ceilings**—1x3 furring strips running perpendicular to the joists provide a cavity for free air circulation, which often compromises the insulation performance, especially near eaves and in cathedral ceilings. Once nailed in place, they also make it very difficult to install insulation properly. This is another area where money can be saved while thermal performance is improved.

- **Higher R-values in sloped ceilings** can be achieved with smaller framing by adding sister joists with plywood gussets (see Figure 12.9) or by adding a continuous layer of rigid insulation on the underside of the roof rafters.

FIGURE 12.1

Insulating around plumbing, wiring, and other obstacles

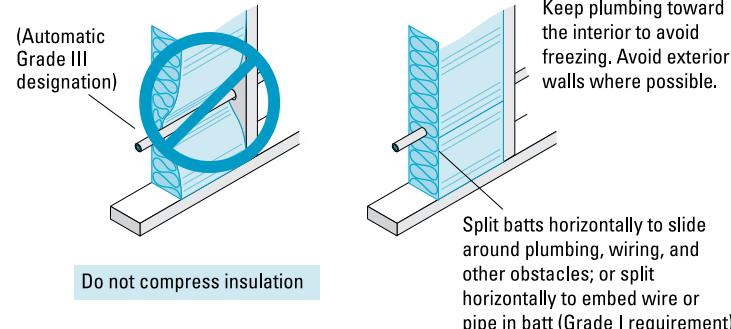
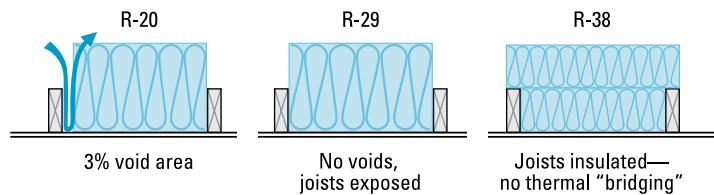


FIGURE 12.2

Effective R-value of insulation

This schematic shows the effect of insulation installation quality and technique on effective (or installed) R-values. Note that the same depth of insulation (12", nominally R-38) is used in all three cases.



CAUTION: Most of initial R-value is lost as void area increases. For example, increasing the void area above from 3% to just 6% would result in an effective R-value of only 15.

FIGURE 12.3

Face-stapling versus inset stapling kraft-faced batts

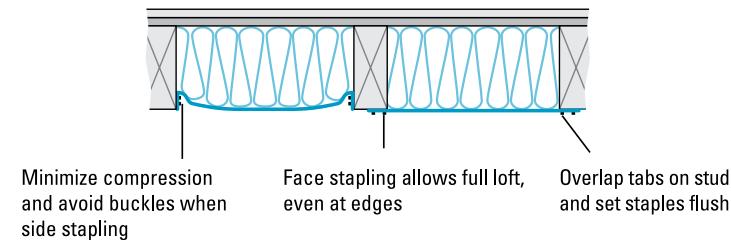


FIGURE 12.4

Conventional truss

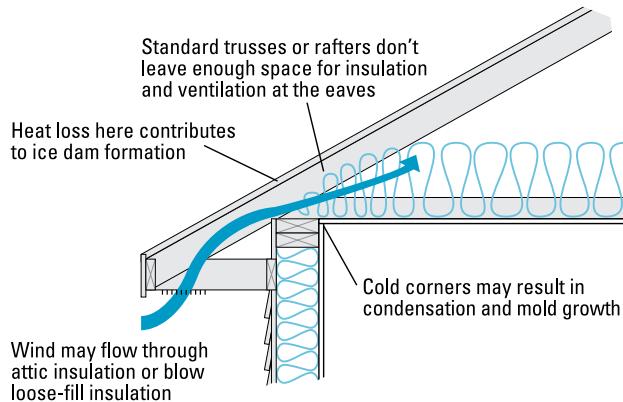


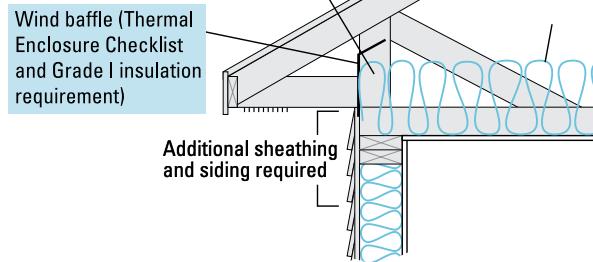
FIGURE 12.5

Raised heel truss

Raised heel trusses can be ordered for any eave height.

Insulation R-value must be the same all the way to the outer edge of the exterior wall

R-value determined by compliance analysis



Credit is given in the code compliance analysis for better performance. See Figures 12.6 and 12.7 for other options.

CAUTION: Trusses must be sized carefully so that the truss heel lines up with the edge of the wall below.

FIGURE 12.6

Conventional truss or rafter with insulated eaves

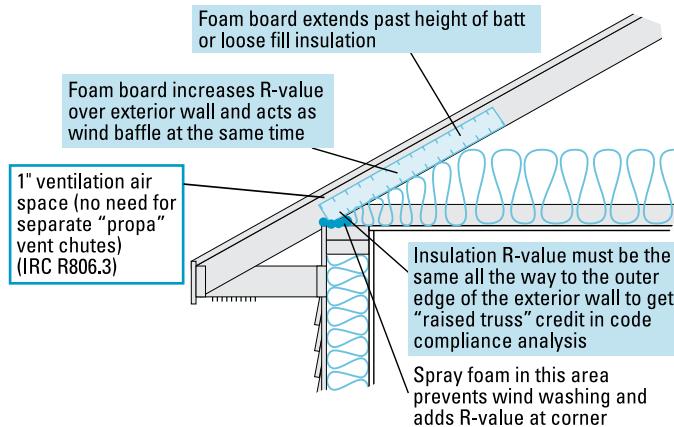


FIGURE 12.7

Conventional rafter with raised plate

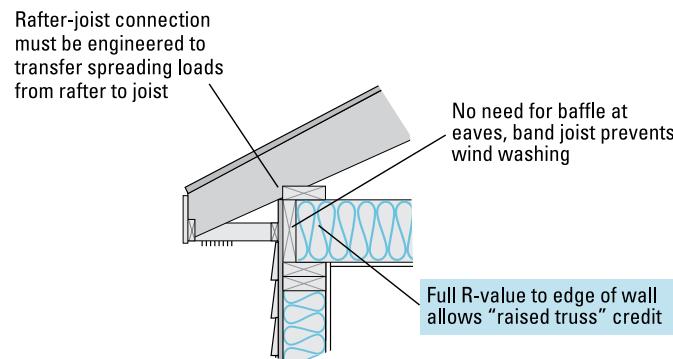


FIGURE 12.8

Vented cathedral ceiling

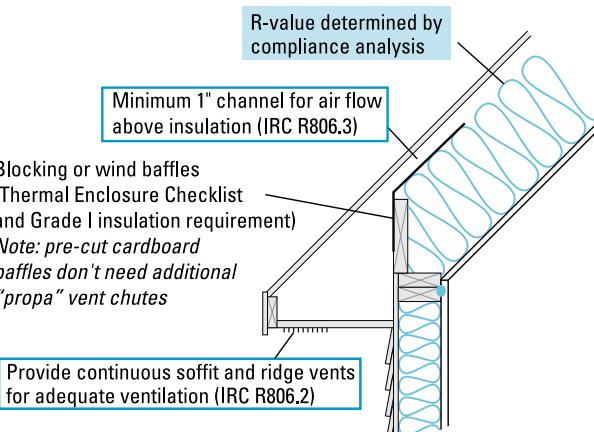
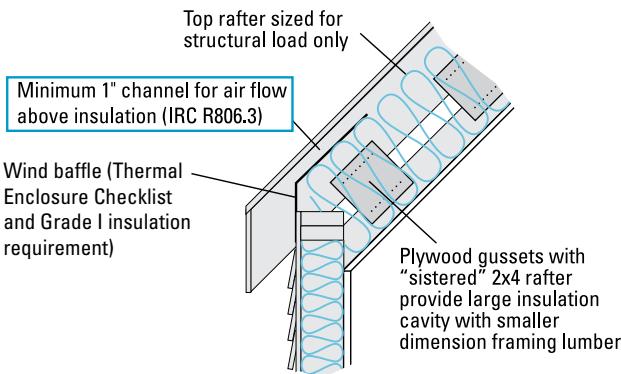


FIGURE 12.9

Cathedral ceiling with built-up rafters



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Health and Safety

There is increasing concern among the public about indoor air quality, moisture, and mold. There is a lot of confusion and misunderstanding; the media often portrays moisture and mold problems as a result of “tight” construction and energy-efficient design. In reality, most of the mold and moisture problems in buildings result from poor exterior water management, followed by thermal and air barrier defects. We are now using more and more building materials that are subject to damage and decay from moisture, and provide better nutrient sources to mold than we did even 10-15 years ago. In fact, the recent emphasis in codes and building practice on using highly vapor permeable exterior sheathings and highly impermeable interior vapor barriers has led to some dramatic building failures resulting from inward-driven moisture in air-conditioned buildings in the North.

Besides the obvious issues of liability and insurance, any builder or designer who wishes to set him- or herself apart can learn the basics about healthy construction, indoor air quality, and especially mold and water management. While you must be careful not to promise a “mold free” environment, you can certainly create an edge for yourself as a designer or builder of homes with “reduced risk” for mold and other air quality concerns. In fact, these concerns may attract a lot more attention among buyers than energy efficiency! In truth, if you design and build a building to be mold resistant, comfortable, and healthy it will be an energy-efficient building as well.

Overview

There are many issues relating to health and safety in residential buildings. Structural integrity and loading of beams, seismic, wind and snow loads, fire protection and egress, basic sanitation, and electrical safety are all covered in building codes and associated mechanical, fire, plumbing and electrical codes. The majority of requirements in most codes are related to life safety issues: prevent the building from falling on people,

help get them out quickly in case of a fire, prevent electrocution and fire hazards from wiring, and provide for clean, reliable potable water and waste removal. These are the immediate, obvious health and safety issues which codes quite properly govern to ensure a basic level of security for homebuyers, and a level playing field for builders. Codes that address other health related concerns such as fresh air ventilation standards are often not clearly understood. And there are some less obvious, but perhaps equally important issues that arise in residential building construction. The purpose of this section is to provide a brief overview of the health and safety aspects of the “house system.” This summary is only a brief introduction to “healthy construction” concepts; more resources are provided in Appendix B.

Are cars safer than homes?

Not really, but you can think about these health and safety issues in the context of shopping for an automobile. Whether you buy a luxury model, a compact economy car, a gas-guzzling sport-utility, or a race car, you expect a certain level of safety. Even though these cars may perform very differently and fill different needs, they all have seat belts, headlights, and air bags. Similarly, even though houses are designed differently to meet many different needs, they should all have a basic set of protections for health and safety beyond those that are found in building codes. Air sealing and water vapor control is just as critical as a seat belt in a car. A mechanical ventilation system is as essential as an airbag. Sealed combustion equipment and a carbon monoxide detector can be compared to headlights and taillights, and a good exterior water management system is the equivalent of windshield wipers. You wouldn’t buy a car without these safety features, and every home should have health and safety as a priority as well.

Priorities

People are becoming more and more aware of the health hazards associated with indoor mold exposure, dust mites, volatile organic compounds, and other airborne contaminants. The incidence of asthma has nearly doubled in the last 20 years, and scientists believe that changes in the indoor environment are the primary cause. Researchers have found that indoor air quality is more polluted—sometimes as much as 100 times more—than outdoor air, and this pollution contributes to allergies, nausea, sinusitis, fatigue, and even extreme chemical sensitivities. In addition, some building scientists suspect that many cases of low-level carbon monoxide poisoning go undiagnosed. Because some people have special health conditions or environmental sensitivities it is difficult to choose a standard that can be applied universally. However, a basic approach to creating a safe, healthy home can be summarized by five principles, all of which involve control of the indoor environment: control of air flows,

water vapor flows, energy flows, particulate flows, and pollution sources and flows. The following paragraphs outline the basic approaches to accomplish this level of control:

- **Air flows**—unintended air flows can be unhealthy for many reasons. These air flows can result from the stack effect (uncontrolled infiltration), duct leaks in basements and attics, unbalanced supply and return duct flows, exhaust fans, or combustion appliance makeup air, all of which create air pressures. Low pressures in basements can increase concentrations of radon, sub-soil pesticide treatments, or other soil gases in the home, as well as increased energy loads. High pressures can result in warm, moisture laden air being pushed into exterior walls or into attics and roof systems, where water vapor can condense and cause mold, mildew and decay. Air flows caused by induced pressures or by the stack effect can conduct deadly car exhaust or fumes from stored chemicals from a garage right into the house, or can backdraft combustion appliances. For all these reasons, it is important to reduce or eliminate unintended air flows from homes. The most important methods to control air flows are as follows:
 - Create a very tight building enclosure by sealing air leaks
 - Design ducts properly for balanced air flows
 - Seal ducts tightly
 - Install only sealed combustion appliances
 - Design and install makeup air for large exhaust appliances if necessary

- **Moisture flows**—Either too much or too little moisture can be unhealthy. High humidity can lead to increased concentrations of biological contaminants such as mold and mold spores, dust mites, mildew, bacteria and viruses. Low humidity can result in increased incidence of respiratory infections, rhinitis (chronic runny nose), and discomfort. It is generally recommended to keep indoor moisture levels between 30 and 60 percent relative humidity (some experts say 35 to 50 percent—also see page 98-99). To do this reliably year-round you must:

- Build a very tight house to reduce the air exchange that dries air in the heating season and brings in humid air in the summer. This includes tightly sealing any ducts that may be outside the thermal boundary.
- Provide controlled ventilation air to reduce moisture loads in winter.
- Provide spot ventilation for bathrooms and kitchens, and any other special sources of moisture loading (pool, hot tub, fish tanks, etc.).
- Provide dehumidification or air conditioning in the summer. Note that oversized air conditioning will not provide the level of

dehumidification needed to keep humidity levels under control; it is actually better to have a slightly undersized air conditioning system for optimum health throughout the summer. With a slightly undersized air conditioner, the indoor air temperature may drift up by a degree or two for a few hours during the hottest days of the year. Indoor air quality, by contrast, will be improved for the vast majority of the humid cooling season.

- **Bulk water leaking into a home** (or from plumbing) can also be a source of high humidity or wet building materials, resulting in many of the same biological contaminants. The following steps are also critical to controlling moisture in buildings:

- Foundation water management systems, such as capillary breaks, footing drainage, rainwater drainage and grading.
- Exterior water management systems such as flashing, siding and roofing details, and a properly installed secondary drainage plane (building paper or housewrap) behind siding. Even better is a vented rain screen, with an air space between the siding and the drainage plane. Be especially careful of flashing details where roofs and decks meet vertical walls. (See EEBA's Builder and Water Management Guides.)

- **Energy flows**—Limiting energy use in a building is related to health, although less directly than the other approaches in this list. In addition to the increased energy loads that result from large air flows through the building enclosure, cold, poorly insulated surfaces may lead to condensation, mold and mildew. It is also possible that when people living in a home are more comfortable, they will tend to be healthier.

- Select windows that have, at a minimum, low-e glazing and argon gas fills. Higher performance glazings, heat mirror films, "warmedge" spacers, and insulated frames will all raise surface temperatures and reduce the chance of condensation and fungal growth on the glass and sash.
- Higher levels of insulation, and framing details that avoid thermal "bridging" of framing from inside to outside surfaces, will also reduce condensation problems and increase comfort.
- Insulate basement walls and slab floors to prevent condensation in the summer, even if they are not in the finished living space.
- Duct insulation and vapor jackets on the exterior of insulated ductwork is critical. Anywhere heating, air conditioning, or exhaust air ducts travel through unconditioned spaces, they should be well insulated, and the vapor jacket on the outside of the insulation

should be uninterrupted. Ducts that carry cold air in winter, located in conditioned space or unconditioned basements, should also be insulated carefully with an exterior vapor jacket installed. (Examples include ventilation supply ducts, or the outdoor exhaust duct from a heat recovery ventilator.)

- **Particulate flows**—Most homes have no real provisions for filtering the indoor air. Filters that are provided with furnaces, central air conditioners or heat pumps are only designed to protect the equipment from damage. Better air filters can reduce many of the particles that can cause health problems. High Efficiency Particulate Attenuation (HEPA) filters are the best grade of filter, which may be indicated for people with existing respiratory ailments. It's a good idea to design a whole-house ventilation system or air distribution system with the capability of adding a HEPA filter later, if needed. Avoid electrostatic filters, ionizers, and any air treatment devices that produce ozone. Also note that any filter must be carefully designed into the air handling system, to account for any pressure resistance created by the filter.
- One advantage of balanced, supply and exhaust ventilation (such as an Energy Recovery Ventilator) is that the fresh air supply can be filtered, unlike exhaust-only systems.
- Whole house air circulation with filtration can be provided by the air handler fan of a furnace or air conditioner. Use a low speed setting on the blower with constant or intermittent circulation. Controls are available that keep track of blower run time to ensure minimum ventilation rates.
- **Contaminant sources and flows**—This category is last on the list, because it has the least to do with energy; however, reduction of contaminant sources is perhaps the most important priority. Sources are many: volatile organic compounds (VOCs) are found in paints, paint strippers, solvents, wood preservatives, and carpeting, as well as stored fuels and automotive products; formaldehydes are found in manufactured wood products such as interior grade plywood, medium density fiberboard (MDF), carpets, and furniture; stored household chemicals such as cleaning products, aerosol sprays, and moth repellents are often toxic; and pesticide and herbicide treatments may be present immediately around or stored in the home. Radon gas can be drawn into the house from below the ground, if it is present. Some of these products are not under the control of the builder or designer of the home, but many of them are. Reduction, separation and dilution are the main strategies to reduce contaminant exposures.
- Source reduction is the most effective way to reduce exposure. If you reduce the source, you need less separation and dilution. Use

of low VOC paints, glues and finishes, hard surface flooring (wood or tile) instead of carpeting, wood cabinets or sealed MDF, and non-toxic wood preservative treatments all have the potential to improve the health of the occupants.

Most of these options are within the scope of the builder to influence.

- Separation from the living space of those contaminants that can not be eliminated is the next best strategy to reduce exposure. One aspect of this that is often overlooked is the elimination of unwanted air flows; be sure to keep air that has a high likelihood of contamination away from the people in the house. These areas especially include garages, combustion appliances, and the earth around the foundation. These air flows are under direct control of the builder, although builders rarely pay attention to them.
- Dilution is the last strategy, and by no means least important. Fresh air ventilation is important to help ensure that contaminants that are present (or may be introduced after the house is finished) can be reduced to safe levels. At a minimum every home should have a simple exhaust only ventilation system; balanced supply and exhaust systems with or without heat recovery allow filtration and control the source of the supply air.
- Radon pre-mitigation is a form of controlling contaminant flows. Every basement or on-grade slab should have at least 4" of uniform, washed stone underneath, 1/2" to 1-1/2" diameter, with no fine particles. Put it under the insulation if you are insulating the slab. Radon levels should be tested after occupancy by an EPA-certified lab. If high levels are found the stone will allow for effective subslab depressurization with a fan to be added later. At a minimum, install a short stub of 4" PVC pipe vertically through the slab, left 4-6" above and capped off. The bottom end should be in the stone layer. Even better, run the pipe right up through the roof, and if a fan needs to be added later it can be easily installed in the attic with a minimum of disruption.

Appendix A

R-Value/U-Factor Average Worksheet

COMPONENT DESCRIPTION	R-VALUE	U-FACTOR (1/R-VALUE)	AREA	UA (U-FACTOR x AREA)

TOTAL AREA = **TOTAL UA =**

$$\frac{\text{TOTAL AREA}}{\text{TOTAL UA}} = \frac{\text{TOTAL UA}}{\text{TOTAL AREA}} = \frac{\text{WEIGHTED AVERAGE R-VALUE}}{\text{WEIGHTED AVERAGE U-FACTOR}}$$

$$\frac{\text{TOTAL UA}}{\text{TOTAL AREA}} = \frac{\text{TOTAL AREA}}{\text{TOTAL UA}} = \frac{\text{WEIGHTED AVERAGE U-FACTOR}}{\text{WEIGHTED AVERAGE R-VALUE}}$$

If you wish, make extra copies of this page. A similar worksheet can be found in the REScheck support materials from www.energycodes.gov (see Appendix B).

This worksheet can help you calculate the overall R-value or U-factor of groups of components that have different thermal performance. You can use it to calculate the average R-value of two or more ceiling, wall or floor areas that have different insulation levels; or to get the average U-factor of different types of windows or doors.

You may find this especially useful if you are using a prescriptive compliance method for a house or an addition. This is the only way that you can get a performance "trade off" using the prescriptive method, although you can only trade off performance within each component type.

The examples on the following page show how to calculate an overall R-value for a ceiling with an uninsulated attic hatch, and the overall U-factor for a group of windows that have a U-factor of 0.32 and a patio door that has a U-factor of 0.42.

General Building Science

Builder's Guide-Cold Climate (2004)

Energy and Environmental
Building Association
Bloomington, MN
(952) 881-1098
www.eeba.org

Building Science for Building Enclosures (2005)
by John Straube and Eric Burnett

Building Science Press, Inc.
Westford, MA
www.buildingsciencepress.com

Water in Buildings: An Architects Guide to Moisture and Mold (2005)
by William B. Rose

John Wiley & Sons, Inc.
Hoboken, NJ
(201)748-6011
www.wiley.com

Foundations and Basements

Building Concrete Homes with Insulating Concrete Forms (1996), an instructive video

Insulating Concrete Forms Construction Manual (1996)

The Portland Cement Association's Guide to Concrete Homebuilding Systems (1995)

Portland Cement Association
Skokie, IL
(847) 966-6200
www.cement.org
www.concretehomes.com

Design Guide for Frost-Protected Shallow Foundations (1996)

NAHB Research Center
Upper Marlboro, MD
(800) 638-8556
www.nahrc.org

Framing/Alternatives

Cost Effective Home Building: A Design Construction Handbook (1994)

NAHB Bookstore
Washington, DC
(800) 223-2665
www.builderbooks.com

Building with Structural Insulated Panels (2002) by Michael Morley

The Taunton Press
Newtown, CT
(203) 426-8171
(800) 477-8727
www.taunton.com

"Advanced Framing," *The Journal of Light Construction*

Williston, VT
(802) 879-3335
www.jlconline.com

"The Future of Framing is Here" (*Fine Homebuilding*, October/November 2005), by Joseph Lstiburek.

The Taunton Press
Newtown, CT
(203) 426-8171
(800) 477-8727
www.taunton.com

Passive Solar, Windows

Guidelines for Home Building and accompanying BuilderGuide (1990)

a passive solar design software
Sustainable Industries
Building Council
Washington, DC
(202) 628-7400
www.sbicouncil.org

Certified Products Directory (updated annually)

National Fenestration Rating Council
Silver Spring, MD
(301) 589-1776
www.nfrc.org

Residential Windows: A Guide to New Technologies and Energy Performance (2nd ed.-2000) by John Carmody, Stephen Selkowitz, and Lisa Heschong

WW. Norton & Co., Inc.
New York, NY
(800) 223-4830

RESFEN 3.1 (1999), an energy use calculation software

Lawrence Berkeley National Laboratory
Berkeley, CA
(510) 486-4000
windows.lbl.gov/software/resfen/

Mechanical Systems and Ductwork

ASHRAE Fundamentals 1997

American Society of
Heating, Refrigeration and
Air Conditioning Engineers
Atlanta, GA
(404) 636-8400
www.ashrae.org

Consumer's Directory of Certified Efficiency Ratings for Residential Heating and Water Heating Equipment (updated twice annually)

Gas Appliance Manufacturers
Association, Inc.
Arlington, VA
(703) 525-7060
www.gamanet.org

Directory of Certified Unitary Equipment Standards (updated twice annually)

Air Conditioning and
Refrigeration Institute
Arlington, VA
(703) 524-8800
www.ari.org

Duct Leakage Diagnostics and Repair (1995), an instructive video

The Energy Conservatory
Minneapolis, MN
(612) 827-1117
www.energyconservatory.com

HRAI Residential Mechanical Ventilation Manual

Heating, Refrigeration and Air Conditioning Institute of Canada
5045 Orbitor Drive, Building 11, Suite 300
Mississauga, Ontario, Canada L4W 4Y4
800-267-2231 or (905) 602-4700
www.hrai.ca/site/skilltech/hraicatalogue

Residential Duct Systems: Manual D (1995)

Residential Load Calculation: Manual J (8th ed.-2002)

Air Conditioning Contractors
of America
Arlington, VA
(703) 575-4477
www.acca.org

Your Home Cooling Energy Guide (1992) by John Krigger

Saturn Resource Management
Helena, MT
(800) 735-0577
www.srm.org

Air Sealing, Moisture Control, Indoor Air Quality, and Ventilation

Healthy House Building, A Design and Construction Guide (2nd ed.-1997) by John Bower

Moisture Control Handbook: Principles and Practices for Residential and Small Commercial Buildings (1993) by Joseph Lstiburek and John Carmody

Understanding Ventilation: How to Design, Select and Install Residential Ventilation Systems (1995) by John Bower

Water Management Guide (2004) by Joseph Lstiburek

Energy and Environmental
Building Association
Bloomington, MN
(952) 881-1098
www.eeba.org

The Inside Story: A Guide to Indoor Air Quality (1995), EPA 402-K-93-007

Building Air Quality (1991) 402-F-91-102

Consumer's Guide to Radon Reduction (2003), EPA 402-K-03-002

Environmental Protection Agency
Washington, DC
www.epa.gov/iaq
www.epa.gov/radon/construc.html

Residential Mechanical Ventilation (1997)

Heating, Refrigerating and Air Conditioning Institute of Canada
Mississauga, Ontario, Canada
(800) 267-2231
www.hrai.ca

Insulation

Cellulose Insulation
Manufacturer's Association

Dayton, OH
(937) 222-2462
1-888-881-CIMA
www.cellulose.org

North American Insulation
Manufacturer's Association

Alexandria, VA
(703) 684-0084
www.naima.org

Energy Efficiency—General

Insulate and Weatherize (2002)
by Bruce Harley

Build Like a Pro series
The Taunton Press
Newtown, CT
(203) 426-8171
(800) 477-8727
www.taunton.com

Residential Energy (3rd ed.-2000)
by John Krigger

Saturn Resource Management
Helena, MT
(800) 735-0577
www.srmi.biz

Publications—Other Books

Canadian Home Builder's Association Builders Manual

Canadian Home Builder's Association
Ottawa, Ontario
(613) 230-3060
www.chba.ca

Green Building Guidelines (3rd ed.-2003)

Sustainable Building Industries Council
Washington, DC
(202) 628-7400
www.sbicouncil.org

Environmental Resource Guide on CD-ROM

Iris Communications, Inc.
Eugene, OR
(541) 767-0355
(800) 346-0104
www.oikos.com

Publications — Periodicals and Catalogs

Energy Design Update

Aspen Publishers, Inc.
New York, NY
(800) 638-8437
www.aspenpublishers.com

EEBA Excellence: Newsletter of the Energy and Environmental Building Association

Bloomington, MN
(952) 881-1098
www.eeba.org

Environmental Building News
Brattleboro, VT
(802) 257-7300
(800) 861-0954
www.buildinggreen.com

Fine Home Building
The Taunton Press
Newtown, CT
(203) 426-8171
(800) 477-8727
www.taunton.com/finehomebuilding

Home Energy Magazine
Berkeley, CA
(510) 524-5405
www.homeenergy.org

Journal of Light Construction
Williston, VT
(800) 375-5981
www.jlconline.com

Product Distributors

The Energy Conservatory
Minneapolis, MN
(612) 827-1117
www.energyconservatory.com

Energy Federation, Inc.
Westboro, MA
(800) 876-0660
www.efi.org

Positive Energy Conservation Products
Boulder, CO
(303) 444-4340
(800) 488-4340
www.positive-energy.com

Shelter Supply, Inc.
Lakeville, MN
(952) 898-4500
(800) 762-8399
www.sheltersupply.com

Tamarack Technologies
Precision Ventilation Products
West Wareham, MA
(800) 222-5932
www.tamtech.com

Organizations

Advanced Energy Corporation
Raleigh, NC
(919) 857-9000
www.advancedenergy.org

Affordable Comfort Inc.
Waynesburg, PA
(724) 627-5200
www.affordablecomfort.org

Building Code Assistance Project (BCAP)
Washington, DC
(202) 857-0666
www.bcap-energy.org

Conservation Services Group
Westboro, MA
(508) 836-9500
www.csgrp.com

Energy and Environmental Building Association
Bloomington, MN
(952) 881-1098
www.eeba.org

Florida Solar Energy Center
A Research Institute of the
University of Central Florida
Cocoa, FL
(321) 638-1000
www.fsec.ucf.edu

National Association of Home Builders
Research Center
Upper Marlboro, MD
(800) 638-8556
www.nahrc.org

New Hampshire Sustainable Energy Association
Concord, NH
603-22NHSEA or 603-226-4732
www.nhsea.org

Residential Energy Performance Association
New Hampshire
www.repa-nh.org

Residential Energy Services Network
Oceanside, CA
(760) 806-3448
www.natresnet.org

Rocky Mountain Institute
Snowmass, CO
(970) 927-3851
www.rmi.org

Southface Energy Institute
Atlanta, GA
(404) 872-3549
www.southface.org

Sustainable Buildings Industry Council
Washington, DC
(202) 628-7400
www.sbicouncil.org

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B

Resources

Appendix C

NH EC-1 Form and Air Barrier Criteria

New Hampshire
Residential Energy Code Application
 for Certification of Compliance for New Construction, Additions and/or Renovations
 (EC-1 Form)

Minimum Provisions Effective Date: April 1, 2010

Owner/Owner Builder: Company Name (if applicable)	General Contractor: Company Name		
Name: _____	Name: _____		
Mail Address: _____	Mail Address: _____		
Town/City: _____ State: _____ Zip: _____	Town/City: _____ State: _____ Zip: _____		
Phone: _____ Cell: _____	Phone: _____ Cell: _____		
E-Mail: _____			
Location of Proposed Structure: Tax Map #: _____ Lot #: _____ Street: _____ Town/City: _____ County: _____			
Type of Construction: <input type="checkbox"/> Residential <input type="checkbox"/> Small Commercial <input type="checkbox"/> New Building <input type="checkbox"/> Renovation <input type="checkbox"/> Addition <input type="checkbox"/> Thermally Isolated Sunroom <input type="checkbox"/> Modular Home: the site contractor must submit this form detailing supplementary rooms and floor and/or basement insulation unless the floor insulation is installed or provided by the manufacturer and no heated space is added.			
Zone 5 <input type="checkbox"/> Cheshire, Hillsborough, Rockingham or Strafford except the town of Durham Zone 6 <input type="checkbox"/> All other counties and the town of Durham			
Total New Conditioned^a Floor Area: _____ ft ²			
Heating System: (if new system is being installed) Annual Fuel Use Efficiency (AFUE): _____ % Fuel Type(s): <input type="checkbox"/> Oil <input type="checkbox"/> Natural Gas <input type="checkbox"/> Propane (LP) <input type="checkbox"/> Electric <input type="checkbox"/> Wood <input type="checkbox"/> Other Heating System Type: <input type="checkbox"/> Hot Water <input type="checkbox"/> Hot Air <input type="checkbox"/> Stove <input type="checkbox"/> Resistance <input type="checkbox"/> Heat Pump <input type="checkbox"/> Geothermal			
Structure is EXEMPT INCOMPLETE: <input type="checkbox"/> Mobile Home <input type="checkbox"/> On an historic register <input type="checkbox"/> Low energy use (less than 1 watt/ ft ²)			
Basement or Crawl Space: (*a conditioned space is one being heated or cooled, containing un-insulated ducts or with a fixed opening into a conditioned space. Walls must be insulated) <input type="checkbox"/> Yes (Walls must be insulated) <input type="checkbox"/> No <input type="checkbox"/> Full Basement <input type="checkbox"/> Walk Out Basement <input type="checkbox"/> Slab on Grade <input type="checkbox"/> Other			
Form Submitted by: <input type="checkbox"/> Owner <input type="checkbox"/> Builder <input type="checkbox"/> Designer <input type="checkbox"/> Other Architects must certify plans meet code; no form required			
<small>1 hereby certify that all the information contained in this application is true and correct, and construction shall comply in all respects with the terms and specifications of the approval given by the Public Utilities Commission and with the New Hampshire Code for Energy Conservation in New Building Construction.</small>			
Signature _____ Print Name _____ Date _____			
<table border="1" style="width: 100%; border-collapse: collapse;"> <tr> <td style="width: 50%; padding: 5px;"> Official Use Only Date Complete Application Received: _____ Approval Number: _____ </td> <td style="width: 50%; padding: 5px;"> Approved by: _____ Date: _____ Stamp: _____ <small>Print: <input type="checkbox"/> 1, <input type="checkbox"/> 2, <input type="checkbox"/> 3, <input type="checkbox"/> 4 Email: <input type="checkbox"/> 1, <input type="checkbox"/> 2, <input type="checkbox"/> 3, <input type="checkbox"/> 4</small> </td> </tr> </table>		Official Use Only Date Complete Application Received: _____ Approval Number: _____	Approved by: _____ Date: _____ Stamp: _____ <small>Print: <input type="checkbox"/> 1, <input type="checkbox"/> 2, <input type="checkbox"/> 3, <input type="checkbox"/> 4 Email: <input type="checkbox"/> 1, <input type="checkbox"/> 2, <input type="checkbox"/> 3, <input type="checkbox"/> 4</small>
Official Use Only Date Complete Application Received: _____ Approval Number: _____	Approved by: _____ Date: _____ Stamp: _____ <small>Print: <input type="checkbox"/> 1, <input type="checkbox"/> 2, <input type="checkbox"/> 3, <input type="checkbox"/> 4 Email: <input type="checkbox"/> 1, <input type="checkbox"/> 2, <input type="checkbox"/> 3, <input type="checkbox"/> 4</small>		

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C

Criteria

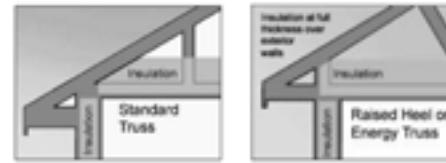
EC-1 Form page 1

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New Hampshire Energy Code EC-1		Certification No.:
<p>Code effective April, 2010</p> <p>Directions: Complete the "Your Proposed Structure" columns. No measurements or calculations are needed. If you at least meet the New Hampshire Energy Code requirements, your project will be approved. Write N/A in any section that does not apply to your project. Submit pages 1 and 2 only. If your planned structure cannot meet these requirements, consider downloading RIScheck from http://www.energycodesplus.com/rischeck/download.aspx and use trade-offs to prove compliance.</p> <p>You are encouraged to build with higher R-values and lower U-values than you report here. The "Required U or U' Values" are the lowest permitted in NH.</p>		
Building Section	Required R or U Values	YOUR PROPOSED STRUCTURE
Window U Factor (lower U is better)	U .35 (maximum) U-38 (if log walls) U .50 (Thermally Isolated Sunrooms only)	<p>Write Planned R and U Values</p> <p>Write in U-Value</p> <p>Brands / Models / Insulation type and thickness (if known)</p> <p>Window Type: <input type="radio"/> Low-e <input type="radio"/> Low-e Argon <input type="checkbox"/> Check if: <input type="checkbox"/> Sunroom <input type="checkbox"/> Log Walls</p>
Skylights	U .60	Write in R-Value
Flat Ceiling ¹ or	 	<p>NOTE: R-38 will be deemed to satisfy the requirement for R-49 if the full R-38 insulation value is maintained over the outside plates. If using only R-38 (Zone 5) or R-38 (Zone 6), you must verify that you'll maintain R-38 over the plates by checking the box below.</p> <p>→ <input type="checkbox"/> By checking this box, I certify that this structure is being built with a raised energy truss or that the full R-value of the ceiling insulation will be maintained over the outside plates.</p>
Flat Ceiling with Raised or Energy Trusses R-value	R-38 (Zone 5) R-49 (Zone 6) if using the above construction technique	R-30 (Zone 5) R-38 (Zone 6) if maintaining the full R value over the plates
Sloped or Cathedral Ceiling	R-30 or 38 if more than 500 ft sq or 20% of total ceiling area R-24 (Thermally Isolated Sunrooms only)	Write in R-Value <input type="checkbox"/> Check if Sunroom
Above Grade Wall ² R-value	R-20 Cavity insulation only or R-13 plus R-5 Cavity plus Continuous insulation R-13 (Thermally Isolated Sunrooms only)	Write in R-Value <input type="checkbox"/> Check if Sunroom <p>Log walls must comply with ICC408, have an average minimum wall thickness of 3" or greater and must have overall glazing of U-.11 or lower and heating AFE of 99% (gas) or 84% (oil) and meet all other energy code requirements.</p>
Door U-Value	U .25 (maximum)	Write in U-Value
Floor R Value (Basement ceiling)	R-30 or Insulation sufficient to fill joint cavity	Write in R-Value
Basement or Crawl Space Wall R Value	R-13 Cavity insulation or R-10 Continuous insulation (Zone 5) R-19 Cavity insulation or R-15 Continuous insulation (Zone 6)	Write in R-Value <p>If conditioning the basement you must insulate Basement Walls. If not, you may insulate either Floor or Basement Walls and/or Slab Edge</p>
Slab Edge ³ R Value	R-10 2' (Zone 5) 4' (Zone 6) (see drawing pg. 3) and R-5 if the slab is heated	Write in R-Value
Air Sealing	Planned Air Sealing Test Method → By checking this box, I certify that I understand that I have two approaches to demonstrating compliance with air sealing requirements.	<input type="checkbox"/> Blower Door <input type="checkbox"/> Visual Inspect <p>The visual inspection certification must be consistent with the requirements of Table-402.4.2 (page 4) and the method of compliance planned and approved by the local jurisdiction</p>
<p>Submit pages 1 and 2 to: NH Public Utilities Commission, 21 South Fruit Street Ste 1B, Concord NH 03301 Fax: 603.271.3878 e-mail: energycodes@puc.nh.gov</p> <p>EC-1 Form - page 2</p>		

Footnotes to Residential Energy Code Application for Certification of Compliance

¹ Ceilings with attic spaces: R-30 in Zone 5 or R-38 in Zone 6 will be deemed to satisfy the requirement for R-38 or R-49 respectively wherever the full height of uncompressed R-30 or R-38 insulation extends over the wall top plate at the eaves or the full R-value is maintained. This is accomplished by using a raised heel or energy truss as shown in the diagram below or by using higher R-value insulation over the plates.

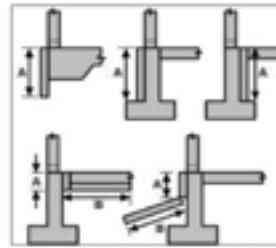


² R-13 + R-5 means R-13 cavity insulation plus R-5 insulated sheathing. If structural sheathing covers 25 percent or less of the exterior, R-5 sheathing is not required where the structural sheathing is placed. If structural sheathing covers more than 25 percent of exterior, the structural sheathing must be supplemented with insulated sheathing of at least R-2.

³ Slab edge insulation must start at the top of the slab edge and extend a total of two (Zone 5) or four feet (Zone 6). Insulation may go straight down, out at an angle away from the building, or along the slab edge and then under the slab. A slab is a concrete floor within 1' of grade level. See diagram below.

The top edge of insulation installed between the exterior wall and the interior slab may be mitered at a 45 degree angle away from the exterior wall.

Allowable Slab Insulation Configurations



A or A + B must equal two feet in Zone 5 or four feet in Zone 6

MODULAR HOMES must be certified by the NH Department of Safety. Unless the floor insulation is provided by the manufacturer this form must be submitted. This form must also be submitted if the basement is to be insulated or supplementary heated space is added to the home upon or after it is set.

AIR BARRIER AND INSULATION INSPECTION COMPONENT CRITERIA	
Required Elements Check List (see page 2 AIR SEALING) IECC Code section 402.4.2	
This page must be provided to the building inspector at final inspection.	
<input checked="" type="checkbox"/> Check here Certification No.:	
Air barrier and thermal barrier	Exterior thermal envelope insulation for framed walls is installed in substantial contact and continuous alignment with building envelope air barrier. Breaks or joints in the air barrier are filled or repaired. Air-permeable insulation is not used as a sealing material. Air-permeable insulation is inside of an air barrier.
Ceiling/attic	Air barrier in any dropped ceiling/soffit is substantially aligned with insulation and any gaps are sealed. Attic access (except unvented attic), knee wall door, or drop down stair is sealed.
Walls	Comers and headers are insulated. Junction of foundation and sill plate is sealed.
Windows and doors	Space between window/door jambs and framing is sealed.
Rim joists	Rim joists are insulated and include an air barrier.
Floors (including above-garage and cantilevered floors)	Insulation is installed to maintain permanent contact with underside of sub floor decking. Air barrier is installed at any exposed edge of insulation.
Crawl space walls	Insulation is permanently attached to walls. Exposed earth in unvented crawl spaces is covered with Class I vapor retarder with overlapping joints taped.
Shafts, penetrations	Duct shafts, utility penetrations, knee walls and flue shafts opening to exterior or unconditioned space are sealed.
Narrow cavities	Batts in narrow cavities are cut to fit, or narrow cavities are filled by sprayed blown.
Garage separation	Air sealing is provided between the garage and conditioned spaces.
Recessed lighting	Recessed light fixtures are air tight, IC rated, and sealed to drywall. Exception—fixtures in conditioned space.
Plumbing and wiring	Insulation is placed between outside and pipes. Batt insulation is cut to fit around wiring and plumbing, or sprayed blown insulation extends behind piping and wiring.
Shower/tub on exterior wall	Showers and tubs on exterior walls have insulation and an air barrier separating them from the exterior wall.
Electrical/phone box on exterior walls	Air barrier extends behind boxes or air sealed-type boxes are installed.
Common wall	Air barrier is installed in common wall between dwelling units. HVAC register boots HVAC register boots that penetrate building envelope are sealed to sub-floor or drywall.
Fireplace	Fireplace walls include an air barrier.

NEW HAMPSHIRE ENERGY CODE	
Summary of Basic Requirements. See IECC 2009 Code Book for complete details	
These 2 pages must be provided to the building inspector at final inspection or retained.	
<input checked="" type="checkbox"/> Check here Certification No.:	
Air Leakage Code section 402.4	All joints, seams, penetrations and openings in the thermal envelope including those around windows and door assemblies, utility penetrations, dropped ceilings or chases, knee walls, behind tubs and showers, separating unheated garages from the thermal envelope, common walls between dwelling units, attic access, rim joist junction and all other openings in the building envelope that are sources of air leakage must be caulked, gasketed, weather-stripped or otherwise sealed.
Air Sealing and Insulation Code Section 402.4.2	Building envelope air tightness and insulation installation shall be demonstrated to comply with requirements by Blower Door testing to less than 7 air changes/hr at 50 Pa or a visual inspection per page 4 of this document. The local Building Official may require an independent 3 rd party to conduct the visual inspection. See page 4.
Testing Option Code Section 402.4.2.1 or Visual Option Code Section 402.4.2.1	While the Blower Door Test and/or Visual Option are methods of demonstrating compliance many of the general requirements as defined by this checklist (pages 5 & 6) must still be met. Blower Door Test conducted by: Result (at 50 Pa): _____ CFM. Interior Volume: _____ CF _____ ACH or Structure passes Visual Inspection: _____ signed _____ date
Fireplaces Code Section 402.4.3	New wood-burning fireplaces shall have gasketed doors and outdoor combustion air.
Recessed Lighting Code Section 402.4.5	Recessed lights must be type IC rated and labeled as meeting ASTM E 283 and sealed with a gasket or caulk between the housing and the interior wall or ceiling covering.
Electrical Power and Lighting Systems Code section 404	A minimum of 50% of the lamps in permanently installed lighting fixtures shall be high efficacy lamps.
High-Efficacy Lamps Code section 202	Compact fluorescent lamps, T-8 or smaller diameter linear fluorescent lamps, or lamps with a minimum efficacy of: 1. 60 lumens per watt for lamps over 40 watts, 2. 50 lumens per watt for lamps over 15 watts to 40 watts, and 3. 40 lumens per watt for lamps 15 watts or less.
Materials and Insulation Information Code section 102.1	Materials and equipment must be identified so that code compliance can be determined. Manufacturer manuals for all installed heating, cooling and service water heating equipment must be provided. Insulation R-values, glazing and door U-values and heating and cooling equipment efficiency must be clearly marked on the building plans, drawings or specifications.
Pull-Down Attic Stairs, Attic Hatch, and Knee Wall Doors Code section 402.2.3	Should be insulated to a level equal to the surrounding surfaces and tightly sealed and weather-stripped at the opening.

• • • • •

Full size Attic or Basement Entry Doors Code section 403.2	All doors leading from a conditioned space into an unconditioned attic or enclosed attic or basement stairwell should be insulated and weather-stripped exterior rated door units. One door is exempt.
Duct Insulation Code section 403.2	Supply ducts in attics must be insulated to at least R-8. All other ducts must be insulated to at least R-6. Exception: Ducts or portions thereof located completely inside the building thermal envelope.
Duct Construction Code sections 403.2.2 & .3	Ducts, air handlers, filter boxes, and building cavities used as ducts must be sealed. Joints and seams must comply with Section M1601.4.3 of the <i>International Residential Code</i> . Building framing cavities must not be used as supply ducts.
Duct Testing Code sections 403.2.2 & .3	Duct tightness shall be verified by testing unless the air handler and all ducts are located within the conditioned space. Test conducted by: _____ Duct test result at 25 Pa: _____ Post construction or _____ Rough-in test
Temperature Controls Code section 403.1 & .3.1	At least one thermostat must be provided for each separate heating and cooling system. Hot air systems must be equipped with a programmable thermostat. Heat pumps having supplementary electric-resistance heat must have controls that, except during defrost, prevent supplemental heat operation when the heat pump compressor can meet the heating load.
Mechanical System Piping Insulation Code section 403.3	Mechanical system piping capable of conveying fluids at temperatures above 105°F or below 55°F must be insulated to R-3.
Circulating Hot Water Systems Code section 403.4 & NH amendments	Circulating service water systems must include an automatic or readily accessible manual switch that can turn off the hot water circulating pump when the system is not in use. Circulating domestic hot water system piping shall be insulated to R-4.
Mechanical Ventilation Code section 403.5	Outdoor air intakes and exhausts must have automatic or gravity dampers that close when the ventilation system is not operating.
Equipment Sizing Code section 403.6	Heating and cooling equipment must be sized in accordance with Section M1401.3 of the <i>International Residential Code</i> .
Certificate Code section 401.3	A permanent certificate, completed by the builder or registered design professional, must be posted on or in the electrical distribution panel. It must list the R-values of insulation installed in or on the ceiling, walls, foundation, and ducts outside the conditioned spaces; U-factors and SHOC for fenestration. The certificate must also list the type and efficiency of heating, cooling and service water heating equipment.

NEW HAMPSHIRE ENERGY CODE Summary of Basic Requirements Page 2

These 2 pages must be provided to the building inspector at final inspection or retained.

Appendix D

IECC Residential Compliance Checklists Zone 5 and 6

Residential Data Collection Checklist 2009 International Energy Conservation Code Climate Zone 5 and Marine 4								
Building ID: _____	Date: _____	Name of Evaluator(s): _____						
Building Contact: Name: _____		Phone: _____	Email: _____					
Building Name & Address: _____								
Subdivision: _____		Lot #: _____	Conditioned Floor Area: _____ SF					
State: _____ County: _____		Jurisdiction: _____						
Compliance Approach (check all that apply): Prescriptive			Trade-Off	Performance				
Compliance Software Used: _____			Green Building/Above-Code Program: _____					
Building Type: 1- and 2-Family, Detached		Single Family	Modular	Townhouse				
Multifamily: Apartment		Condominium						
Project Type: New Building		Existing Building Addition			Existing Building Renovation			
IECC Section #	Pre-Inspection/Plan Review	Code Value	Verified Value	Y	N	Y/O	N/A	Comments/Assumptions
403.2 IRC	Construction drawings and documentation available. Documentation sufficiently demonstrates energy code compliance.							
403.6 IRC	HVAC calculations: Heating system size(s); Cooling system size(s)		Efficiency kW/h					
Additional Comments/Assumptions: _____								

General building information only required if different than above Building ID: _____

Date: _____ Name of Evaluator(s): _____

Building Name & Address: _____ Conditioned Floor Area: _____ sf

Building Contact: Name: _____ Phone: _____ Email: _____

Compliance Approach (check all that apply): Prescriptive Trade-Off Performance

Compliance Software Used: _____ Green Building/Above-Code Program: _____

IECC Section #	Foundation Inspection:	Code Value	Verified Value	Complies				Comments/Assumptions
				Y	N	N/O	N/A	
402.1.1	Slab edge insulation R-value.	Unheated: R-10 Heated: R-15	R-10 Unheated Heated					
505.2	Slab edge insulation installed per manufacturer's instructions.							
402.1.1	Slab edge insulation depth/length.	2 ft.	R-					
402.1.1	Basement wall exterior insulation R-value.	Continuous: R-10	R-10					
505.2	Basement wall exterior insulation installed per manufacturer's instructions.							
402.2.7	Basement wall exterior insulation depth.	10 ft. or to basement floor	R-					
402.2.5	Crawl space wall insulation (R-value).	Continuous: R-10 Cavity: R-13	R-10 R-13					
505.2	Crawl space wall insulation installed per manufacturer's instructions.							
402.2.9	Crawl space continuous vapor retarder installed with joints insulated by 6 inches and sealed, and extending at least 6" up the stem wall.							
505.2.1	Exposed foundation insulation protection.							
402.2.9	Snow melt controls.							

Additional Comments/Assumptions: _____

6/9/2011 Page 2

General building information only required if different than above Building ID: _____

Date: _____ Name of Evaluator(s): _____

Building Name & Address: _____ Conditioned Floor Area: _____ sf

Building Contact: Name: _____ Phone: _____ Email: _____

Compliance Approach (check all that apply): Prescriptive Trade-Off Performance

Compliance Software Used: _____ Green Building/Above-Code Program: _____

IECC Section #	Framing / Rough-in Inspection	Code Value	Verified Value	Complies				Comments/Assumptions
				Y	N	N/O	N/A	
402.1.1	Door U-factor:	U-0.35	U-					
402.3.4								
402.1.1	Glazing U-factor (area-weighted average):	U-0.35 (0.45 max)	U-					
402.3.1								
402.3.3, 402.5								
402.1.1	Glazing SHGC value, including sunrooms (area-weighted average). ¹	N/A	SHGC-					
402.3.2								
402.3.3								
505.1.3	Glazing labeled for U-factor (or default values used).							
402.1.1	Skylight U-factor. ²	U-0.6 (0.75 max) ³	U-					
402.3.3, 402.5								
402.1.1, 402.3.3	Skylight SHGC value. ⁴	N/A	SHGC-					
505.1.3	Skylights labeled for U-factor (or default values used).							
402.3.5	Sunroom glazing U-factor:	U-0.5	U-					
402.3.5	Sunroom skylight U-factor:	U-0.75	U-					
402.1.1	Mass wall exterior insulation R-value.	R-13	R-					
505.2	Mass wall exterior insulation installed per manufacturer's instructions.							
403.2.1	Duct insulation:	Attic Supply: R-6 R-6 Other: R-6						
403.2.2	Duct sealing complies with listed sealing methods.							
403.2.2	Duct tightness via rough-in test. If applicable, verification via post-construction test should be marked N/A.	Across System: 6 cfm Per Air Handler: 6 cfm						
403.2.3	Building cavities NOT used for supply ducts.							
402.4.5	IC-rated recessed lighting fixtures meet infiltration criteria.							
403.3	MUHC piping insulation.	R-3	R-					
403.4	Circulating hot-water piping insulation.	R-2	R-					
403.5	Compensators installed on all outdoor intake and exhaust openings.							
402.4.4	Glazed fenestration air leakage: 0.3 cfm/ft ²	0.3 cfm/ft ²						
402.4.4	Swinging door air leakage: 0.5 cfm/ft ²	0.5 cfm/ft ²						
402.4.4	Fenestration and doors labeled for air leakage:							

Additional Comments/Assumptions: _____

General building information only required if different than above

Building ID: _____

Date: _____ Name of Evaluator(s): _____

Building Name & Address: _____ Conditioned Floor Area: _____ SF

Building Contact: Name: _____ Phone: _____ Email: _____

Compliance Approach (check all that apply): Prescriptive Trade-Off Performance

Compliance Software Used: _____ Green Building/Above-Code Program: _____

IECC Section #	Insulation inspection	Code Value	Verified Value	Complies	Comments/Assumptions	
				Y	N	N/A
402.1.1	Floor insulation R-value.	Wood R-30 Steel See Footnote	R-_____			
402.1.5						
402.1.6						
402.1.7						
403.2	Floor insulation installed per manufacturer's instructions, and in substantial contact with the subfloor.					
403.2.1	Wall insulation R-value.	Wood R-20 or R-13+R-5 Mass R-17 Steel See Footnote	R-_____			
403.2.5						
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General building information only required if different than above						Building ID: _____
Date: _____	Name of Evaluator(s): _____					
Building Name & Address: _____			Conditioned Floor Area: _____			SF
Building Contact: Name: _____			Phone: _____	Email: _____		
Compliance Approach (check all that apply):			Prescriptive	Trade-Off	Performance	
Compliance Software Used: _____			Green Building/Above-Code Program: _____			
IIBDG Section #	Final Inspection Provisions	Code Value	Verified Value	Complies		Comments/Assumptions
402.1.1	Ceiling insulation R-value.	Wood R-38 Steel Truss Steel Joist R-49	R-_____	Y	N	N/A
402.2.1						
402.2.2						
402.2.3						
402.3.1,1.1,1	Ceiling insulation installed per manufacturer's instructions. Blown insulation marked every 300 ft ² .	R-38	R-_____			
402.3.2	Attic access hatch and door insulation.	R-38	R-_____			
402.3.3	Duct tightness via post-construction test, if applicable, verification via rough-in test should be marked N/A.	80% Ductless 8 cm Access System 12 cm	cm			
403.6	Heating and cooling equipment type and capacity as per plans.					
404.1	Lighting - 50% of lamps are high efficacy.					
404.3	Certificate posted.					
404.4.3	Wood burning fireplace - gasified doors and outdoor air for combustion.					
405.1.1	Programmable thermostats installed on forced air furnaces.					
405.1.2	Heat pump Thermostat installed on heat pumps.					
405.4	Circulating service hot water systems have automatic or accessible manual controls.					
405.9	Pool heaters, covers, and automatic or accessible manual controls.					
Additional Comments/Assumptions: _____						
<p>KEY: 1 High Impact (Tier 1) 2 Medium Impact (Tier 2) 3 Low Impact (Tier 3)</p>						

Residential Data Collection Checklist
 2009 International Energy Conservation Code
 Climate Zone 6

Building ID _____ Date _____ Name of Evaluator(s) _____

Building Contact Name: _____ Phone: _____ Email: _____

Building Name & Address: _____

Subdivision: _____ Lot #: _____ Conditioned Floor Area: _____

State: _____ County: _____ Jurisdiction: _____

Compliance Approach (check all that apply): Prescriptive Trade-Off Performance

Compliance Software Used: _____ Green Building/Above-Code Program: _____

Building Type: 1- and 2-Family Detached: Single Family Modular Townhouse

Multifamily: Apartment Condominium

Project Type: New Building Existing Building Addition Existing Building Renovation

IECC Section #	Pre-Inspection/Plan Review	Code Value	Verified Value	Complies				Comments/Assumptions
				Y	N	N/G	N/A	
IECC 2 (pre) [checkmark]	Construction drawings and documentation available. Documentation sufficiently demonstrates energy code compliance.							
IECC 6 (pre) [checkmark]	HVAC loads calculations: Heating system size(s): Cooling system size(s):		kBtu: _____					

Additional Comments/Assumptions: _____

General building information only required if different than above							Building ID: _____																																																																																																																								
Date: _____	Name of Evaluator(s): _____	Building Name & Address: _____	Conditioned Floor Area: _____ SF	Building Contact: Name: _____	Phone: _____	Email: _____																																																																																																																									
Compliance Approach (check all that apply): Prescriptive Trade-Off Performance																																																																																																																															
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Building ID: _____

Date: _____ Name of Evaluator(s): _____

Building Name & Address: _____ Conditioned Floor Area: _____ SF

Building Contact: Name: _____ Phone: _____ Email: _____

Compliance Approach (check all that apply): Prescriptive Trade-Off Performance

Compliance Software Used: _____ Green Building/Above-Code Program: _____

IECC Section #	Insulation Inspection	Code Value	Verified Value	Complies			Comments/Assumptions
				Y	N	N/A	
R02.1.1 R02.2.5 R02.2.6 [R1.12]	Floor insulation R-value.	Wood: R-20 Steel: See footnote	R-_____				
R02.2.7 [R1.12]	Floor insulation installed per manufacturer's instructions, and in substantial contact with the subfloor.						
R02.1.1 R02.2.5 R02.2.4 [R1.12]	Wall insulation R-value.	Wood: R-20 or R-13+R-8 Mass: R-19 Steel: See footnote	R-_____				
R02.2.7 [R1.12]	Wall insulation installed per manufacturer's instructions.						
R02.1.1 [R1.12]	Basement wall interior insulation R-value.	Continuous: R-15 Cavity: R-19	R-_____				
R02.2.7 [R1.12]	Basement wall interior insulation installed per manufacturer's instructions.						
R02.2.7 [R1.12]	Basement wall interior insulation depth.	10 ft or to basement floor	R-_____				
R02.2.11 [R1.12]	Sunroom wall insulation R-value.	R-13	R-_____				
R02.2.7 [R1.12]	Sunroom wall insulation installed per manufacturer's instructions.						
R02.2.11 [R1.12]	Sunroom ceiling insulation R-value.	R-24	R-_____				
R02.2.7 [R1.12]	Sunroom ceiling insulation installed per manufacturer's instructions.						
R02.4.2 R02.4.2.1 [R1.12]	Air sealing complies with sealing requirements via blower door test. If applicable, verification via visual inspection should be marked N/A.	ACH 50 4.7	ACH 50 + _____				
R02.4.1 R02.4.2 [R1.12]	All installed insulation labeled or installed R-value provided.						
R02.4.1 R02.4.2 [R1.12]	Air sealing of all openings and penetrations via visual inspection:						
	• Site-built penetrations						
	• Window/floor openings						
	• Utility penetrations						
	• Attic access openings						
	If applicable, verification via blower door should be marked N/A.						

R02.4.1
R02.4.2
[R1.12]

Air sealing of all envelope joints and seams via visual inspection:

- Dropped ceilings
- Knee walls
- Assemblies separating garage
- Tubs and showers
- Common walls between units
- Rim joist junctions

If applicable, verification via blower door should be marked N/A.

R02.4.1
R02.4.2
[R1.12]

Air sealing of all other sources of infiltration, including air barrier, via visual inspection. If applicable, verification via blower door should be marked N/A.

Additional Comments/Assumptions: _____

Appendix D



General building information only required if different than above

Building ID: _____

Date: _____ Name of Evaluator(s): _____

Building Name & Address: _____ Conditioned Floor Area: _____ SF

Building Contact: Name: _____ Phone: _____ Email: _____

Compliance Approach (check all that apply): Prescriptive Trade-Off Performance

Compliance Software Used: _____ Green Building/Above-Code Program: _____

IECC Section #	Final Inspection Provisions	Code Value	Verified Value	Complies				Comments/Assumptions
				Y	N	N/A	N/A	
I602.1.1 [I602.1.1]	Ceiling insulation R-value.	Wood R-49 Steel Truss R-36@R-5 Steel Joist R-49	R-_____					
I602.2.1 [I602.2.1]	Ceiling insulation installed per manufacturer's instructions. Blown insulation marked every 300 ft ² .							
I602.2.2 [I602.2.2]	Attic access hatch and door insulation.	R-49	R-_____					
I602.2.3 [I602.2.3]	Duct tightness via post-construction test. If applicable, verification via rough-in test should be marked NUA.							
I602.3.1 [I602.3.1]	Heating and cooling equipment type and capacity as per plans.							
I604.1 [I604.1]	Lighting - 50% of lamps are high efficacy.							
I607.3 [I607.3]	Certificate posted.							
I602.4.3 [I602.4.3]	Wood burning fireplaces - gasketed doors and outdoor air for combustion.							
I603.1.1 [I603.1.1]	Programmable thermostat installed on forced air furnaces.							
I603.1.2 [I603.1.2]	Heat pump thermostat installed on heat pumps.							
I603.4 [I603.4]	Circulating service hot water systems have automatic or accessible manual controls.							
I603.9 [I603.9]	Pool heaters, covers, and automatic or accessible manual controls.							

Additional Comments/Assumptions: _____

KEY: 1 High Impact (Tier 1) 2 Medium Impact (Tier 2) 3 Low Impact (Tier 3)